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The COST-ED model (Costs of Schools, Training, and Education) of the instructional process encourages the recognition of management alternatives and potential cost-savings. It is used to calculate the minimum cost of performing specified instructional tasks. COST-ED components are presented as cost modules in a flowchart format for manpower, teachers, facilities, attrition, and student opportunity. Computer-assisted instruction (CAI) is an educational medium which can be described within the context of the COST-ED model. CAI equipment cost factors are defined on the basis of functions performed: instructional process control, curriculum availability, or student-system communication. Radical economic differences between CAI and classroom instruction explain the "all-or-nothing-effect": CAI can be economically justified only if it becomes the dominant mode of instruction in a given instructional environment. Until CAI costs decline, applications will be confined to the military, welfare, and industrial sectors of the nation. The expansion of CAI into public education depends on methods of submitting, soliciting, and evaluating CAI projects and on public policy measures in behalf of the educational technology industry. (TI)

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COST STUDY OF EDUCATIONAL MEDIA SYSTEMS AND THEIR EQUIPMENT COMPONENTS

Volume III

A Supplementary Report: Computer Assisted Instruction.

Final report • Contract OEC 1-7-079006-5139 • May 1968
U.S. Department of Health, Education and Welfare
Office of Education
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FINAL REPORT

Contract No. OEC-1-7-079006-5139

COST STUDY OF EDUCATIONAL MEDIA SYSTEMS AND THEIR EQUIPMENT COMPONENTS

Volume III
A Supplementary Report: Computer Assisted Instruction

GENERAL LEARNING COPRORATION
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5454 Wisconsin Avenue
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May 1968

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U. S. DEPARTMENT OF
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PREFACE

The objectives of this report are threefold: (a) to develop a general model which allows the greatest freedom to determine potential cost savings through the use of CAI; (b) to establish the need for basic guidelines for evaluating and soliciting proposals using CAI; and (c) to describe the present CAI industry, its problems, and public policy measures which provide feasible alternatives for the timely development and potential expansion of CAI into public education.

The basic guidelines for evaluating and soliciting proposals concerning the use of CAI are only suggestions and are not to be considered as a directive from the Office of Education.

GENERAL MODEL

Introduction

The intent of the following section is to provide a basis for the consideration of economic factors pertinent to the conduct of instruction, in general, and to the use of computer-assisted instruction, in particular.

Efficient management of instructional enterprises cannot be achieved without an understanding of the underlying economics. This understanding must come from more than a perusal of accounting documents; it must come from knowledge of how relevant costs behave in relation to management action alternatives. The cost model of the instructional process which is described in this section is meant to further this understanding by the clear and graphic portrayal of how costs are incurred and how they react to changes made in the conduct of instruction.

The Need for a Cost Model

The demand for educational and training services in this country (and around the world) is skyrocketing at a time when the rate of technical innovation is also on the steep ascent. The manager of educational enterprises is finding it difficult to remain in control in the face of all these changes. Yet the management of educational and training activities has not changed materially for a very long period.

Very few of the educational activities conducted in this country are managed as independent business-type entities. For this reason, the cost accounting procedures which are available tend generally to serve purposes of fund allocation control or simple fund requirement projections on a year-to-year basis, rather than to develop management-type cost effectiveness information.

Strongly needed at this time is a managerial tool:

- To improve control of activities which will soon comprise more than 10% of our gross national product;
- To assist in important decision making regarding technical innovations; and
- To provide a framework for the development of sound plans and policy at many levels of government and industry.

An economic model of the instructional process can make a key contribution to the satisfaction of these needs by encouraging the recognition of management alternatives and by facilitating break-even and trade-off analysis amongst the alternatives.

The COST-ED model presented below addresses these needs directly. Its name is an acronym derived from Costs of Schools, Training, and Education.

Objectives and Limitations of the Model

The objectives of the model are:

- Identification and isolation of the most important factors contributing to the efficiency with which resources are expended for instructional and training activities;
- Simple statement of the relationships among these factors;
- Facilitation of cost effectiveness analysis at several levels of detail; and
- Applicability to all instructional media and organizational situations.

The model itself consists of:

- A pattern of cost factor definition and aggregation;
- A statement of mathematical relationships among cost factors and desired summary statistics; and
- Procedures for the use of these factors and relationships for decision-making.

The model is designed to provide a basis for answering the following types of questions:

- How sensitive are summary costs to changes in particular cost factors?
- How sensitive are summary costs to changes in the costs of resources consumed?
- What constitutes the minimal description of an educational medium or a method for conducting instructional activities needed for economic analysis?
- What are trade-offs between constituent resources consumed in instruction?
- What are the opportunity costs of certain alternative management actions not taken?

In its entirety, the COST-ED model is meant to be as general as possible. The need for generality in the model is occasioned by the rapid changes in education today, and by the many different situations to which the model may be applied. The COST-ED model is to be used primarily to assemble estimates of the cost of conducting instruction in different ways. The model is designed to calculate the minimum required cost of performing instruction with specified instructional designs.

A key feature built in to the COST-ED model is the modularity of its components. This is to say, the set of cost factors and relationships comprising the COST-ED model is divided into distinct, but easily interfaced, subsets called modules. With this structure, the general model may be adapted for use in different instructional environments or at different levels of detail simply by proper selection, omission, and adaptation of modular units.

The cost structure of the COST-ED model is based on the criterion of usefulness for cost effectiveness analysis, and, therefore, is not directly patterned after accounting structures in use by the military or local school systems. Thus, proper use of the model may require the translation of available cost data from its source format to the model format. This may often be done most effectively by educated estimation; where more exactness is required, special cost analyses activity may be necessary prior to using the model. An illustration of the translation of data between formats is given in the section describing the New York City Academic High School.

Cost models necessarily represent simplifications of the true cost behavior which they are meant to represent. They are useful because they provide the ability to manipulate cost factors in economic analysis. However, this gain is obtained at the price of lower cost projection accuracy, and this must be kept in mind in reviewing the following material.

One cost factor omitted from consideration in this model is the value of the land required for instructional facilities. This omission may be important especially in urban areas where land may be costly and where land committed to educational purposes incurs the cost of foregone tax revenue. The property value should be taken into account separately in comparing different instructional strategies where these strategies place different requirements on land use. Specifically, a technique such as CAI, which may reduce total student enrollment through speeding up the educational process, may concurrently reduce requirements for instructional buildings and the land on which they are situated. Only facilities costs, such as are represented by the buildings themselves and the equipment they house, are considered in the COST-ED model.

The Approach to the Cost Analysis of Instruction

A conceptual scheme of the instructional process is a necessary prerequisite to the development of a cost structure useful for economic analysis. The scheme employed here views instruction as a process which supports and controls interaction or communication between sources of knowledge (the curriculum) and the learner. From a managerial viewpoint this process may be described by:

- Functions performed,
- Enabling resources required, and
- Operating resources consumed.

An analysis of the functions performed in any training situation shows that those directly relating to the "learning communication" of the instructional process comprise only a part of the entire set of activities performed. Generally speaking, there are two major categories of activities involved: those which are immediately a part of the instructional process, and those which support the performance of the instructional process or provide non-instructional services to the learner. For the purposes of the model developed here, these two general functions will be labelled "instruction" and "student support". The prime criterion for distinguishing between these two functions is an economic one.

- Activities or resources which contribute directly to the achievement of those learning objectives which affect the required duration of instruction are classed as within the "instruction" function.
- Activities or resources which do not directly affect the duration of instruction, but which are utilized only so long as instruction is performed, are within the "student support" category.

Basically, instructional resource consumption enjoys a two-way interdependency with the achievement of learning objectives; the extent of student support resource consumption is dependent upon — but does not directly influence — the achievement of learning objectives.

This distinction may be clarified by the use of several examples. Certainly teachers, student time, classrooms and their furnishings and facilities, and textbooks all more or less directly affect the achievement of those learning objectives which dictate the duration of instruction. On the other hand, athletic facilities — even though they are used for athletics instruction — will be used only until nonathletic learning objectives are achieved, and no more. If a student skips a grade in school, for instance, he is not required to make up the lost year of "gym". On this basis, and despite the instructional objectives which are stated for athletic programs, athletic facilities can be viewed economically as "supporting" the student while he receives other kinds of instruction, and are grouped with "student support" and not "instruction" resources. Clearer examples of student support facilities are school buses, student housing, and lunchrooms. Examples of other "student support" activities which parallel athletics are attendance control, health services, and operational school administration.

Depending on the situational context and the use to be made of the cost model, the two general functions of instruction and student support may be further subdivided into such component subfunctions as the following:

- Instruction
    - Direct Instruction
    - Auxiliary Instruction
    - Testing and Student Evaluation
    - Instruction Preparation

- Student Support
    - Subordinated Instruction
    - Extracurricular Activities
    - Student Housing
    - Student Administration
    - Student Transportation
    - General Administration

The particular headings illustrated above are not essential to the model; the model is designed to accommodate any detailed breakout of the two major functions deemed useful for a particular application.

Enabling resources are here defined as those which are consumed by factors other than direct utilization. Capital resources such as buildings, major items of equipment, and the like fall into this category.

Enabling resources are required for the performance of a function, but they exist and may depreciate independently of whether that function is performed. If an enabling resource depreciates without performance of the function which it could support, an opportunity cost is incurred. This opportunity cost may be considered from either one of two viewpoints: as foregone savings of financial resources, or foregone realization of benefits which would have accrued from fuller use of the resource.

The clearest example of an enabling resource is a school building which depreciates at night when it is not used just as rapidly as during the day when it is used. If school buildings were used around the clock (as they sometimes are in the military), the costs of depreciation would be shared by more students, and the cost of depreciation per student would fall. Not using the buildings around the clock leads to a higher cost per student, and thus to foregone savings when there are a fixed number of students — a foregone savings which may properly be termed an opportunity cost.

Even though there may be very valid social, organizational,or other reasons for not using enabling resources around the clock, failure to do so must be considered economically as incurring an opportunity cost. Strict economic analysis of instructional activities must identify such costs, even if conventional practices are based upon the assumption that the social costs of recapturing these opportunity costs are too great to allow their recapture. Identification of these opportunity costs is especially important now in view of current technological and social trends which may well reverse the past opportunity cost — social cost balance.

The model described below is designed especially to identify enabling resources and the opportunity costs which they may bear. By so doing, the model serves its function of pointing toward ways in which the efficiency of the instructional process may be improved.

Operating resources are those which are consumed only with their utilization. Services and materials such as teacher effort and chalk are examples of operating resources.

Operating resources are generally consumed in one of two fashions:

- As a function of time, and
- As a function of unit volume.

Teacher services, for instance, are consumed and paid for on the basis of time. Textbooks, on the other hand, are consumed on the basis of unit, i.e., student, volume. Although it may seem that most costs are incurred — or could be considered to be incurred — on a time basis, counterexamples could easily be drawn from military training where sizeable unit costs (e.g., for required practice ammunition) appear. Drawing this distinction carefully is needed for accuracy in analyzing cost trade-offs and sensitivities where changes in training time are involved. Provisions are made in the model for both types of charging operating resources.

Design Scheme for the COST-ED Model

The general sequence of activities needed to build a model of the cost behavior of a specified design of the instructional process is shown in Figure 1. Note that the activities begin with a definition of the instructional process to be used, not with a statement of already existing instructional facilities and patterns. This is in accord with the prime use visualized for the model, namely for a cost analysis of new procedures and methods for the conduct of instruction. In cases where the model is to be applied to an existing instructional system, the starting point would be an analysis of existing patterns.

The first step illustrated is the identification of the functions to be performed in the instructional process. How these functions are defined will dictate the overall structure of the cost model that is built. To the extent that great detail is used in isolating many different functions or subfunctions, the resultant model will be complicated. The multiplicity of separate functions identified should be a reflection of the extent of detail desired in the economic analysis.

The next two steps, determining teacher time use pattern and student flow pattern, are actually a part of specifying the instructional process that is to be considered. Since the cost of teachers or other instructional personnel involved generally represents a large fraction of total instructional costs, it is important to expend some effort in specifying how such personnel will be used. Similarily, the student flow pattern is meant to encompass such items as student input, student output, and attrition.

The next step is to determine the requirements for enabling resources. This too may be performed at several levels of detail. In general, the requirements for each particular resource are considered to be dependent on the number of students who may simultaneously use the resource. This is related to the total number of students involved and the scheduling pattern for the use of the resource considered.

The scheduling and usage factors are then used together with the specification of the student flow pattern to develop methods for charging the costs of enabling resources to the performance of each of the separately identified functions.

Since charging costs of enabling resources is based upon the utilization of those resources, this is the point at which opportunity costs may be identified. They are associated with those portions of enabling resource availability which are not used.

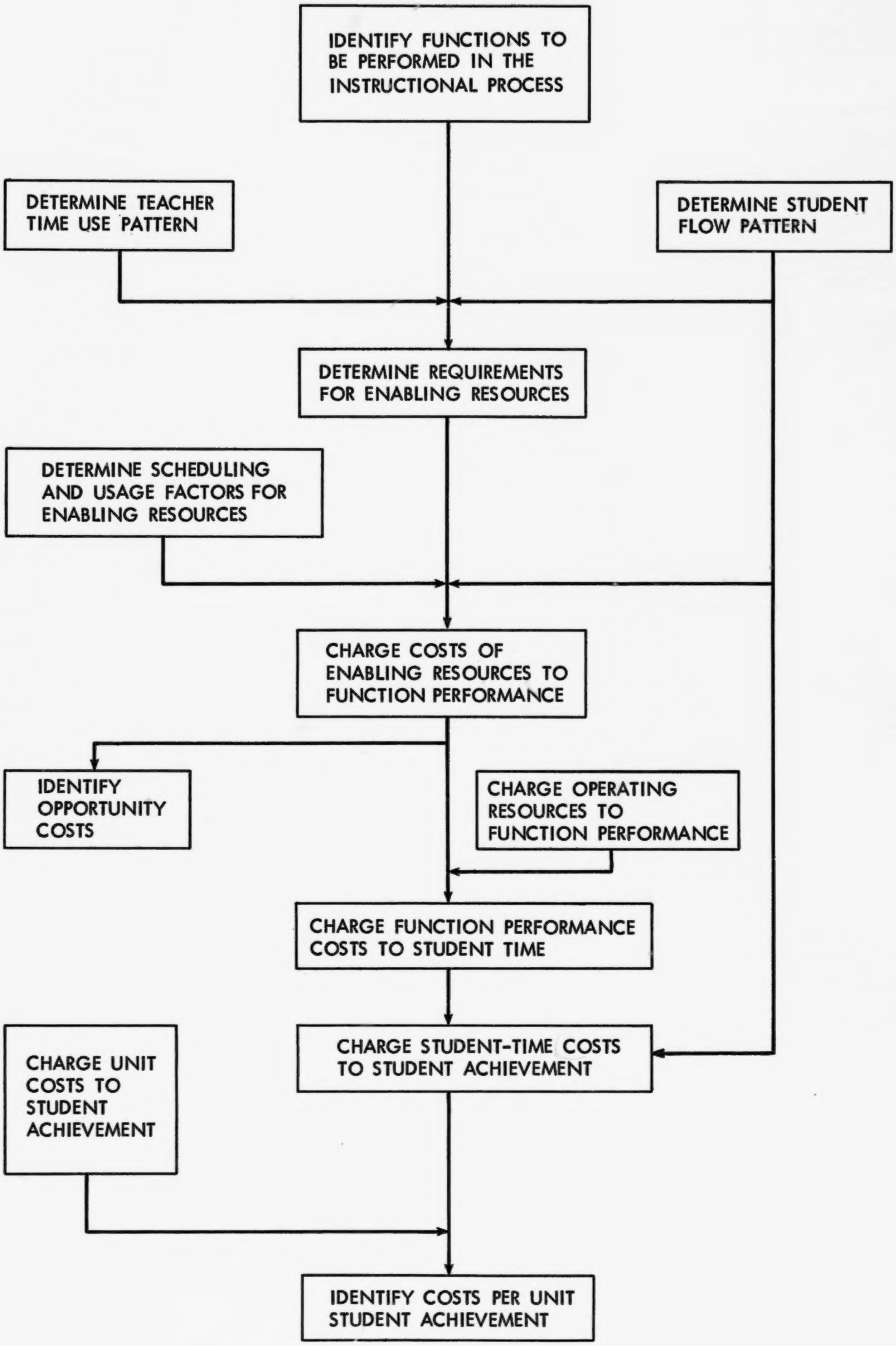

IDENTIFY FUNCTIONS TO BE PERFORMED IN THE INSTRUCTIONAL PROCESS
DETERMINE TEACHER TIME USE PATTERN
DETERMINE STUDENT FLOW PATTERN
DETERMINE REQUIREMENTS FOR ENABLING RESOURCES
DETERMINE SCHEDULING AND USAGE FACTORS FOR ENABLING RESOURCES
CHARGE COSTS OF ENABLING RESOURCES TO FUNCTION PERFORMANCE
IDENTIFY OPPORTUNITY COSTS
CHARGE OPERATING RESOURCES TO FUNCTION PERFORMANCE
CHARGE FUNCTION PERFORMANCE COSTS TO STUDENT TIME
CHARGE UNIT COSTS TO STUDENT ACHIEVEMENT
CHARGE STUDENT-TIME COSTS TO STUDENT ACHIEVEMENT
IDENTIFY COSTS PER UNIT STUDENT ACHIEVEMENT

Figure 1. Design Scheme for the COST-ED Model

Next, all operating resources which are consumed on a time basis are charged to function performance. At this point, all time dependent charges for both enabling resources and operating resources may be combined to develop a single charge for function performance per unit of time.

The student flow pattern is then used to determine how much time each student spends receiving the benefit of each function performed in order to complete a unit of student achievement. The time figures developed are used to apportion the costs of performing each function per unit time to a total cost developed per unit of student achievement.

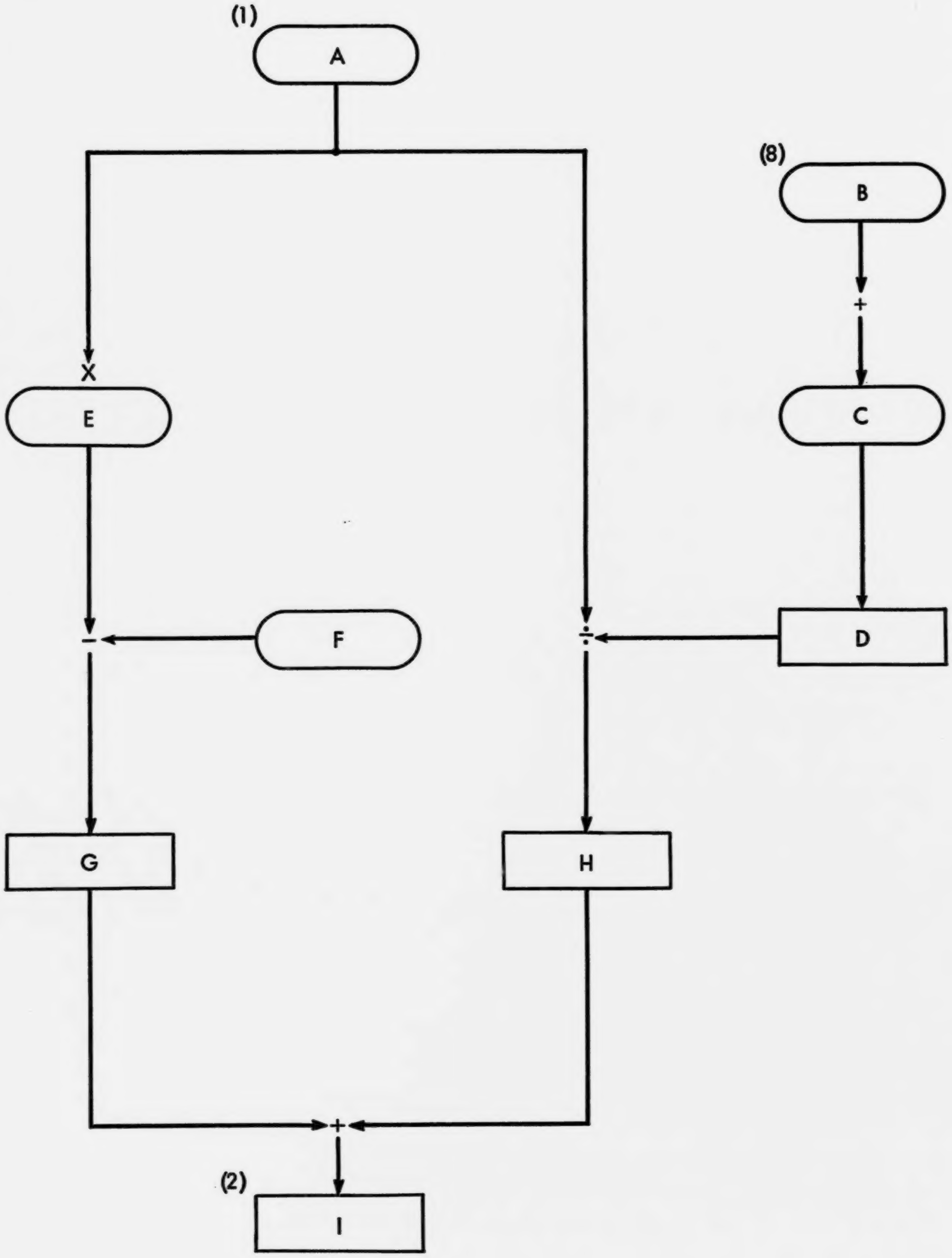
Following this step, costs of operating resources which are consumed on a unit basis, i.e., per unit student achievement, are added to identify a total cost per unit student achievement. By multiplying the cost per student by the total number of students who complete the unit of achievement in a given time period, total instructional costs for this period may be developed.

COST-ED Model Modules

Each of the separable modules which together comprise the COST-ED model is described in this section. Each module consists of a formula which relates several cost factors and shows how detailed factors are used to calculate summary cost statistics of interest.

The cost factor formula comprising each module is depicted in a flowchart format which facilitates the visualization of the relationships among the cost factors. Figure 2 illustrates the format used (the letters A, B, etc. representing cost factors). The following are conventions used in this format.

- Factors enclosed in ovals are original estimates or are calculated in another module.
- Factors enclosed in boxes are calculated in the module under consideration.
- The path of calculation follows the solid arrows.
    - Minuends and dividends precede subtrahends and divisors, which later may be shown entering a path of calculation from the side.
    - Calculations start at factors having no incoming arrows, and proceed to boxed factors. All calculations before a boxed figure are performed to yield the figure in the box before calculation proceeds past the box.
    - Where multiplication/division calculations are in series with addition/subtraction, multiplication/division will be performed first and the product/quotient either added or subtracted from the other figures.


(1)
A
(8)
B
+
X
C
E
F
D
÷
G
H
+
(2)
I

$$I = G + H; \qquad G = A \times E - F$$

$$H = A \div D; \qquad D = B + C$$

$$= A \div (B+C)$$

$$I = (A \times E - F) + (A \div (B+C))$$

$$I = A\,(E + \frac{1}{B+C}) - F$$

Figure 2. Sample Calculation Flowchart

- Where the path of calculation branches apart, the figure calculated up to the branching is used in all branches.
- Where several branches of calculation flow together, the arithmetic symbol at the junction is to be applied to the figures carried forward in each incoming branch.
- Parenthesized numerals indicate points of linkage between the several modules.

Extensive use has been made of mnemonic abbreviations in representing specific cost factors in the flowcharts of the COST-ED modules themselves. These abbreviations are defined in the text of the module descriptions.

Measures of time have not specifically been chosen for many of the time-oriented cost factors used. The symbol "t" is used to denote any measure (e.g., hours, weeks, etc.) convenient for the particular application of the model being made.

NOTE: CONVERSIONS BETWEEN DIFFERENT MEASURES OF TIME USED AT DIFFERENT POINTS IN THE MODEL MAY BE NECESSARY, but these conversions are not shown in the flowcharts.

The description of each of the modules of the COST-ED model given on the following pages is organized as follows:

- Title of Module
- Functions Performed
- Types of Applications
- Calculation Flowchart
- Cost Factors Used
- Linkage with Other Modules

Final Summarization Module

Function Performed. Performs the last combining calculations needed to develop the summary statistics:

- Total cost per unit student achievement.
- Total educational/training cost per unit time.

Types of Applications.

- May be used without support from other modules to combine gross estimates of a minimum number of cost factors into the summary statistics noted above.
- May be used to develop estimates of the dependence of these summary statistics on the cost factors identified within the module.

- May be used to develop estimates of trade-offs among the cost factors identified, subject to a fixed figure for one of the summary statistics.
- May be used with support from other modules to combine detailed calculations into the summary statistics.

Calculation Flowchart. (See Figure 3)

Cost Factors Used.

1. O-P/t: Number of students successfully being graduated from the unit of achievement (e.g., a course of instruction) per unit time.

2. S-t/ACH: Time normally required for an individual student to complete the unit of achievement.

   NOTE 1: The unit of time used here for S-t/ACH need not be the same as the unit used for O-P/t.

   NOTE 2: Although the symbology "S-t" is used to represent "student time", this factor has the dimension of time only; it is not the product of a number of students and an amount of time. In the examples of application of the COST-ED model given below, a product of students and time (e.g., "S-D" or "student-days") is used as a measure of facilities utilization. (See NOTE 1 under Cost Factor 17 in the Facilities Requirements Module.)

3. S-SPT-t/S-t: Ratio between the time spent by a student receiving the benefit of the student support function and the total time spent to complete the unit of achievement.

   NOTE 1: This ratio may be 1.0, indicating that time-dependent cost factors for the student support function are based on total student time; alternatively, this ratio may be less than 1.0, indicating a different basis for estimating time-dependent student support costs (e.g., over only that time in which the student support function is performed in isolation). Whatever basis is used in the numerator of this factor must also be used for its associated cost factors.

NOTE 2: Time may be measured in different units in the numerator and the denominator (e.g., hours/week); the unit of measure in the denominator must match that used in S-t/ACH.

4. S-INST-t/S-t: Ratio between the time spent by a student receiving the benefit of the instruction function and the total time spent to complete the unit of achievement.

NOTE: Notes 1 and 2 under S-SPT-t/S-t above apply.

5. S-SPT-CON-$/S-t: Cost of operating resources consumed in the student support function per unit of the student's time spent receiving the benefit of that function.

NOTE: The unit of time used in this factor must agree with that used in the numerator of S-SPT-t/S-t.

6. S-SPT-F-U-$/S-t: Prorated cost of enabling resource (facilities) usage for the student support function per unit of one student's time spent receiving the benefit of that function.

NOTE: The note under S-SPT-CON-$/S-t applies.

7. S-SPT-$/S-ACH: The sum of all costs of the student support function incurred on a unit basis per student normally completing the unit of achievement which would not be directly affected by a change in the time required (S-t) for completion of that unit of achievement.

8. S-INST-CON-$/S-t: Cost of operating resources consumed in the instruction function per unit of one student's time spent receiving the benefit of that function.

NOTE: This factor is analogous to S-SPT-CON-$/S-t.

9. S-INST-F-U-$/S-t: Prorated cost of enabling resource (facilities) usage for the instruction function per unit of one student's time spent receiving the benefit of that function.

NOTE: This factor is analogous to S-SPT-F-U-$/S-t.

10. S-INST-$/S-ACH: The sum of all costs of the instruction function incurred on a unit basis per student normally completing the unit of achievement.

NOTE: This factor is analogous to S-SPT-$/S-ACH.

11. S-SPT-$/S-t: The sum of all time dependent costs of the student support function incurred per unit of one student's time spent receiving the benefit of that function.

12. INST-$/S-t: The sum of all time-dependent costs of the instruction function incurred per unit of one student's time receiving the benefit of that function.

13. UNIT-$/S-ACH: The sum of all unit costs of all functions incurred per student normally completing the unit of achievement.

14. t-$/S-t: The sum of all time-dependent costs of all functions incurred per student normally completing the unit of achievement.

15. TOT-$/S-ACH: The total cost incurred per student normally completing the unit of achievement.

16. TOT-$/t: Total cost for all graduates of the unit of achievement within a period of time.

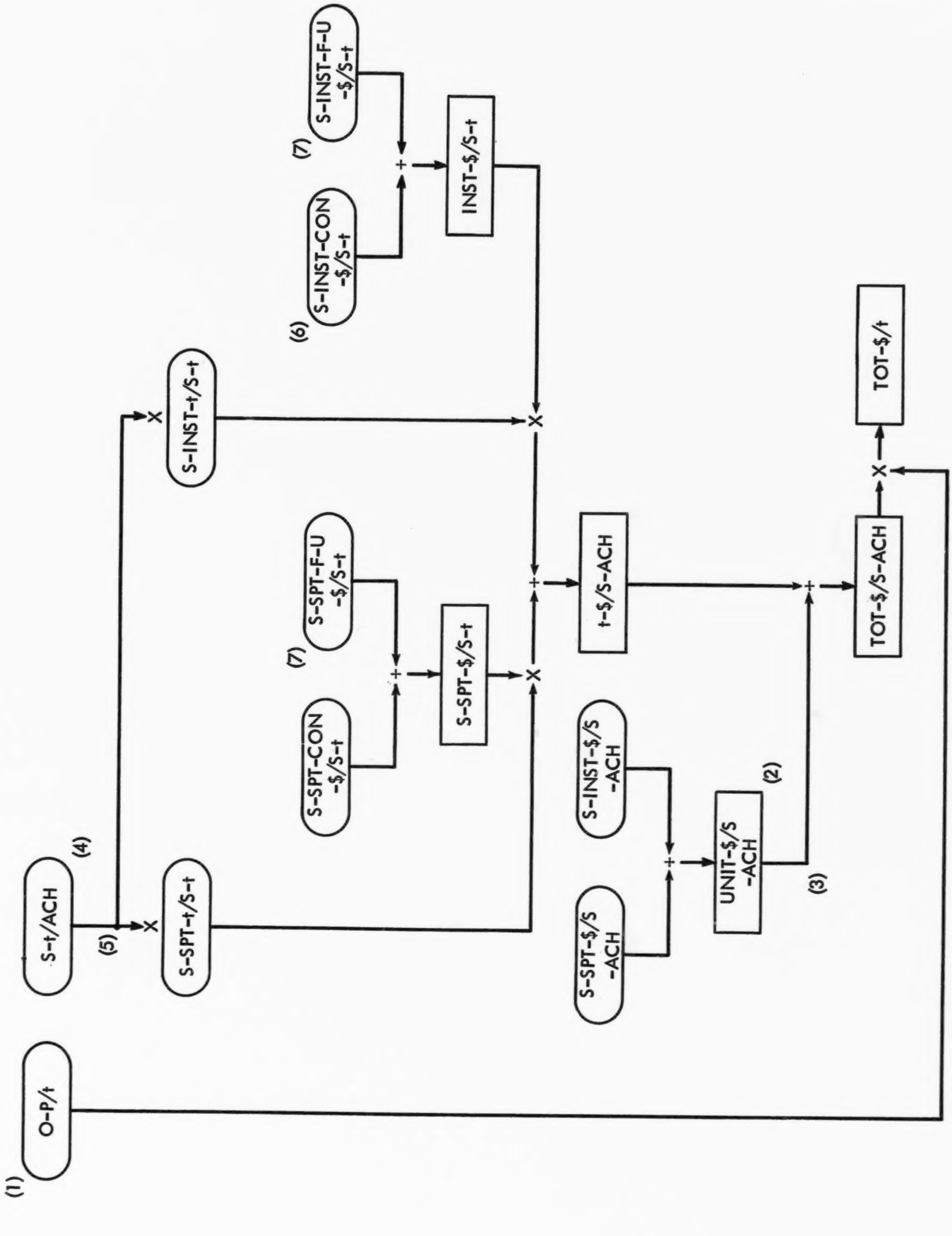
NOTE: The measure of time used here is the same as that used for O-P/t, and need not agree with other measures of time internal to the module.

Linkages with Other Modules.

(1) O-P/t may be a calculated output statistic from the Manpower Requirements Module.

(2) - (3) UNIT-$/S-ACH may be input to the Attrition Correction Module and received back as UNIT-$/S-ACH-*, corrected for the effects of student attrition.

(4) - (5) S-t/ACH may be input to the Attrition Correction Module and received back as S-t/ACH-* corrected for the effects of student attrition and recycling.


(1)
O-P/t
S-t/ACH
(4)
(5)
S-SPT-t/S-t
S-INST-t/S-t
S-SPT-CON -$/S-t
S-SPT-F-U -$/S-t
(7)
S-SPT-$/S-t
S-INST-CON -$/S-t
S-INST-F-U -$/S-t
(6)
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INST-$/S-t
t-$/S-ACH
S-SPT-$/S -ACH
S-INST-$/S -ACH
UNIT-$/S -ACH
(2)
(3)
TOT-$/S-ACH
TOT-$/t
X
+

Figure 3. Final Summarization Module

(6) S-INST-CON-$/S-t may be estimated in part by the Teacher Module. T-INST-$/S-t, the teacher salary and benefit cost per student per unit time receiving teacher instruction, is calculated in that module.

(7) Facilities (enabling resource) utilization costs may be calculated as outputs of the Facilities Requirements Module applied to each identified function.

Manpower Requirements Module

Functions Performed.

- Calculates the number of graduates of the unit of achievement required to support fixed trained manpower requirements when each individual is available for only a fixed period of time (M-AV-t) which is to be split between training and productive service.
- Calculates the average number of students enrolled (S-ENR) at any point in time as a function of required graduate output and training time (S-t).
- Allows calculations of a secondary effect of changes in training time (S-t) upon total training cost — that arising from changes in student input and output needed to maintain a fixed trained manpower level.

Types of Applications.

- Military situations where an enlistee or draftee is available for only a fixed term of service, which must be split between training and duty.
- Organizational training situations where the man trained may be expected to leave the organization or the job at which the training has unique usefulness at an (average) fixed time after commencement of training. (This module would not be applicable if the fixed time of productive service were measured from completion of the training course.)
- Organizational training situations where each man must receive periodic training which removes him from productive service, and his total employment is divided between training and productive service.
- Analysis of occupational educational costs, where a lifetime measures the amount of time available to be split between education and training and where there are fixed national requirements for members of a given occupation.

Calculation Flowchart. (See Figure 4)

Cost Factors Used.

1. S-t/ACH: (See Factor 1 in the Final Summarization Module.)

   NOTE 1: The measure of time used in this factor for this module should be the same measure desired for O-P/t and TOT-$/t (see Final Summarization Module).

   NOTE 2: Time unit conversion may be necessary in the path of calculation between S-t/ACH as used in the Final Summarization Module and its use in this module.

   NOTE 3: When the Attrition Module is used, S-t/GR is used instead of S-t/ACH (see Factors in the Attrition Module).

2. M-R: The number of men required to be in productive service status at all times.

3. M-AV-t: The fixed period of time each man has available for training and subsequent productive service.

4. M-PROD-t: The period of available time remaining, after training time is deducted, which may be spent in productive service.

5. O-P/t: (See Factor in the Final Summarization Module).

6. S-ENR: Number of students enrolled (in-training) for the specified unit of achievement.

Linkages.

(1) O-P/t, calculated in this module, may be used as an input to the Final Summarization Module.

NOTE 1: O-P/t may be an independent variable if it is not regulated by a situation governed by fixed manpower requirements.

NOTE 2: O-P/t may also be calculated by applying any turnover factor (1/M-PROD-t is an example) to M-R.

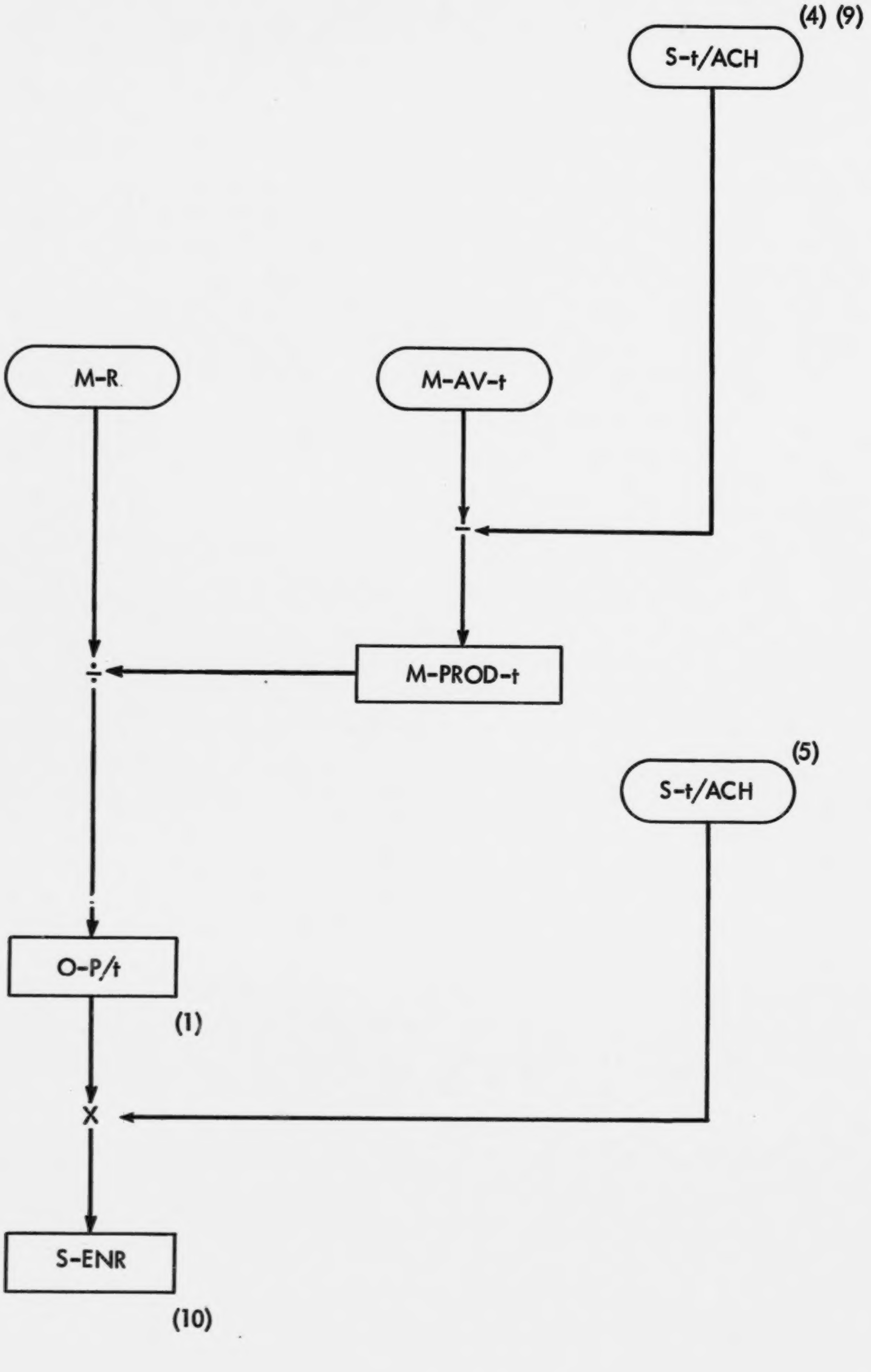

(4) (9)
S-t/ACH
M-R
M-AV-t
÷
M-PROD-t
÷
(5)
S-t/ACH
O-P/t
(1)
X
S-ENR
(10)

Figure 4. Manpower Requirements Module

(4) S-t/ACH (uncorrected for attrition) may be used as input for this module when the Attrition Module is not employed, and is obtained from the Final Summarization Module.

(5) S-t/ACH or S-t/ACH-* should be used here, depending on whether the Attrition Module is employed.

(9) S-t/GR (S-t/ACH corrected for recycling) should be used instead of S-t/ACH when the Attrition Module is employed.

(10) S-ENR may be used as an input to the Facilities Requirements Module and/or the Teacher Module.

Attrition Module

Function Performed. Corrects other factors for the effects of student attrition and recycling.

Types of Applications. May be used where student attrition is a significant factor or is under special study.

Calculation Flowchart. (See Figure 5).

Cost Factors Used.

1. I-P/O-P - 1: Attrition rate expressed as the ratio of students who fail to those who graduate. (The mnemonic is the formula used to calculate this type of attrition factor: student input divided by student output, the quotient less one (1.0).)

2. ATT-t-FAC: The percent of S-t/ACH spent within the instructional process by the average student who fails to graduate.

3. ATT-UNIT-FAC: The percent of UNIT-$/S-ACH consumed by the average student who fails to graduate.

4. RPT-FAC: The ratio of actual to normal time spent within the instructional process by those students who do ultimately graduate from the unit of achievement. This factor is higher than 1.0 if some graduating students are recycled or made to repeat sections of the unit of achievement.

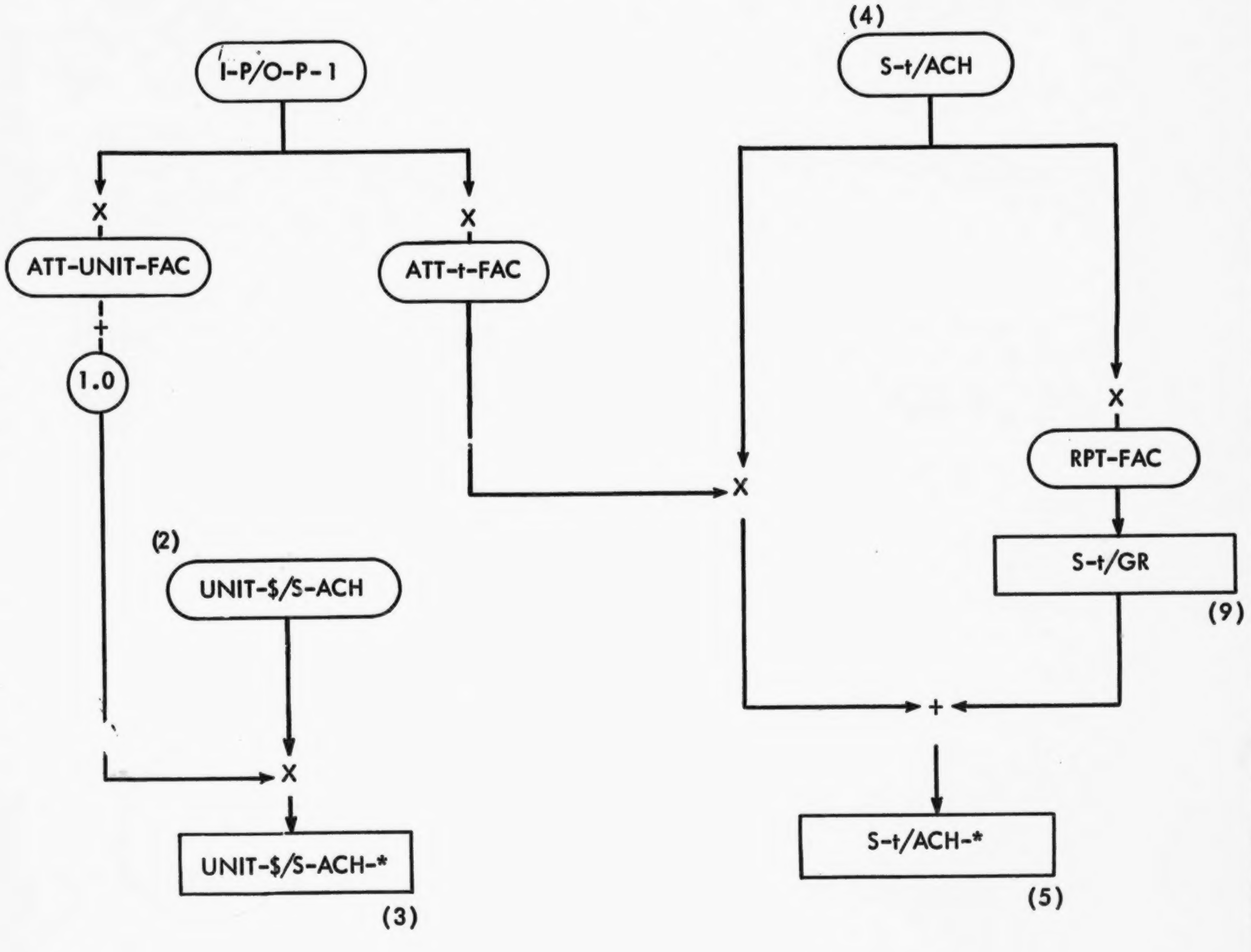

(4)
I-P/O-P-1
S-t/ACH
X
X
ATT-UNIT-FAC
ATT-t-FAC
+
1.0
X
RPT-FAC
X
(2)
UNIT-$/S-ACH
S-t/GR
(9)
+
X
UNIT-$/S-ACH-*
S-t/ACH-*
(3)
(5)

Figure 5. Attrition Module

5. S-t/GR: The average actual time spent within the instructional process by those students who ultimately do graduate from the unit of achievement.

Linkages.

(2) - (3) UNIT-$/S-ACH in the Final Summarization Module is converted to, and replaced by, the attrition-corrected form UNIT-$/S-ACH-* through application of this module.

(4) - (5) S-t/ACH in the Final Summarization Module is converted to, and replaced by, the attrition-corrected form S-t/ACH-* through application of this module.

(9) S-t/GR is used instead of S-t/ACH in the determination of student graduate output requirements in the Manpower Requirements Module when attrition is considered.

Teacher Module

Functions Performed.

- Calculates:
    - The number of teachers required to support the instructional load;
    - The cost of teachers' services per student per unit time; and
    - The annual equivalent cost of unpaid teacher effort which represents "free resources" contributed by the teachers to the instructional process.
- Relates the manner in which a teacher's time is used to instructional costs.
- Recognizes the effect of student-teacher ratio upon teaching costs per student.

Calculation Flowchart. (See Figure 6)

Cost Factors Used.

1. S-ENR: Total number of students enrolled for the unit of achievement under consideration.

2. S-INST-t/S-WK: The number of time units per week spent by each student receiving the benefit of the instruction function.

NOTE: Use of this module is predicated upon identification of the instruction function (or subfunction) with the performance of teaching (or counseling, tutoring, etc.) activities by teachers (instructors, etc.).

3. S/T: The ratio of students to teachers while the instruction function is being conducted.

NOTE: Depending upon usage of teacher time and student time, this ratio may not be the same as the total number of teachers employed divided by the total number of students enrolled.

4. T-INST-t/W-WK: The total teacher-time units spent teaching during the teaching work week. (This is the total of all time spent by all teachers involved.)

NOTE: The unit of time used here must agree with that used for S-INST-t/S-WK.

5. 1 + %-FCD-COM: One (1.0) plus the percent of teaching time which must be spent by each teacher on "forced complementary" activities. (Forced complementary activities may include such items as instruction preparation, administration, etc.)

NOTE: In complex assemblies of model modules where many subfunctions are identified, it may be desirable to break %-FCD-COM into separate components, each corresponding to the percent of teaching time spent on one other identified subfunction. Costs of these subfunctions then, which may include items besides teacher time charges, would ultimately be charged to students or student-time in the Final Summarization Module.

6. T-AV-t/T-WK: Total units of teacher time available (either during or after the working day) for the performance of teaching and forced complementary activities per teacher per working week.

NOTE 1: The unit of time used here must agree with that used for T-INST-t/W-WK.

NOTE 2: This factor will be larger than Factor 8 below (T-PD-t/W-WK) if the teacher customarily spends time after hours on forced complementary activities.

7. 1 + % Tft: One (1.0) plus the percentage of teacher free time. The percent of teacher free time is the percent of the required paid-for work week which the teacher is willing to, or customarily, spends on forced complementary activities outside the required work week.

8. T-PD-t/W-WK: The total number of paid-for teacher-time units per working week. (This is the total of all time units for all teachers involved.)

NOTE: The unit of time used here must agree with that used for T-INST-t/W-WK.

9. % Tft: (See "1 + % Tft" above.)

10. \$/T-PD-t: Cost of salary, benefits, and related overhead per unit of paid teacher time.

NOTE: The unit of time used here must agree with that used for T-INST-t/W-WK.

11. W-WK/YR: The number of teaching work weeks per year.

12. T-R: The number of teachers required to support the instructional load.

13. T-FRE-t-\$: The annual equivalent cost of unpaid teacher free time which represents "free resources" contributed by all the teachers to the instructional process.

NOTE: It would be possible to prorate teacher salary, etc., over all time available T-AV-t instead of just required time T-PD-t, and to consider after hours work paid-for. This approach has not been taken in this model for the following reason: it is not possible to recapture and use in any other way teachers' after-hours work; hence,

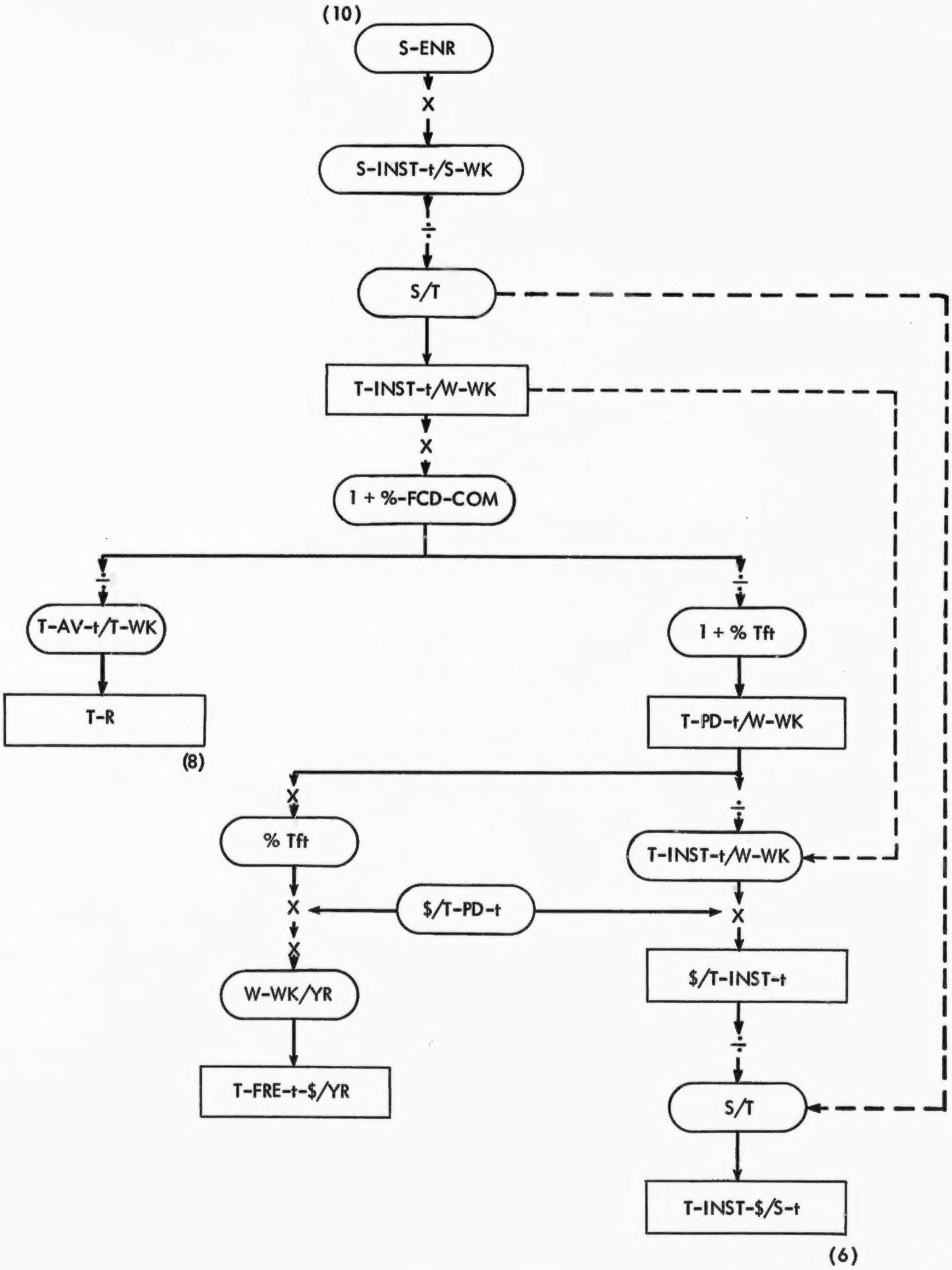

(10)
S-ENR
X
S-INST-t/S-WK
÷
S/T
T-INST-t/W-WK
X
1 + %-FCD-COM
÷
T-AV-t/T-WK
T-R
(8)
÷
1 + % Tft
T-PD-t/W-WK
X
% Tft
÷
T-INST-t/W-WK
X
$/T-PD-t
X
X
W-WK/YR
T-FRE-t-$/YR
$/T-INST-t
÷
S/T
T-INST-$/S-t
(6)

Figure 6. Teacher Module

any dollar figure associated with it does not represent funds which can be traded-off against costs of performing similar work in any other manner. (See "Free Resources" in the section "Key Factors in the Economic Analysis of Instruction".)

14. T-INST-$/S-t: The sum of all teacher time costs per student per unit time spent receiving instruction from teachers.

NOTE: The unit of time used here must agree with that used for S-t/ACH in the Final Summarization Module.

Linkages.

(6) T-INST-$/S-t may be used as a component of S-INST-CON-$/S-t in the Final Summarization Module.

(8) T-R may be used as a facilities requirements variability factor in a Facilities Requirements Module if teacher support facilities are to be isolated.

(10) S-ENR may be an independent variable or may be as calculated in the Manpower Requirements Module.

Facilities Requirements Module

Prefatory Notes.

- Unlike the other modules, the Facilities Requirements Module is not described in terms of specific cost factors. Rather, it is described in terms of a "Facility X" which may represent enabling resources in support of any identified function or subfunction. In any particular application of the COST-ED model, the Facilities Requirements Module may appear many different times, once for each group of separately aggregated facilities.

- The term "facility" is used as a shorter equivalent to "enabling resources". Facilities are seen as divided into two categories denoted as "equipment" and "housing". Equipment is considered uniquely associated with a function; it is assumed that housing of similar characteristics may serve several functions. Costs of equipment operation and maintenance are considered generally to vary with its use; costs of housing operation and maintenance are considered to vary with the capital value of the housing.

- While the facilities component of conventional instruction costs is proportionately much lower than the instructional staff component, this may not be true in the future, and is no longer the case when extensive use of computer-assisted instruction is contemplated. It is for these reasons that this module is quite detailed.

Functions Performed.

- Calculates the size (or number) of facilities needed to support a specified function (Function X or FX) when the facilities are to be used in a specified manner.
- Calculates appropriate charges to the student for usage of facilities.
- Identifies opportunity costs of not making use of available facilities.

Types of Applications.

- May be used in any situation where costly facilities are employed in the instructional process to add detail to less refined estimates.
- May be used to determine comparable minimum facilities requirements and charges when comparing different methods of instruction.
- May be used to calculate the cost effects of changes in schedules of usage of facilities.

Calculation Flowchart. (See Figure 7)

Cost Factors Used.

1. FX-VAR-FAC: Facility X variability factor, representing a measure of any useful basis for calculating facilities requirements.

NOTE 1: Any factor in the COST-ED model, or perhaps a factor not included in the model, may be used as a FX-VAR-FAC. As examples, student enrollment (S-ENR) would be a useful starting point for estimating student support facilities requirements, and the number of teachers required (T-R) may be used as a FX-VAR-FAC for teacher support facilities, if these are to be separately identified.

NOTE 2: The criterion for choosing a given factor as a FX-VAR-FAC is that usage of the Facility X as measurable by the product of that factor and a measure of time. For example, usage of a student support facility, the requirements for which are considered variable on S-ENR, would be expressed as the product of students (using the facility) and time (the average time during which each student uses the facility).

2. FX-PK-FAC: Peak factor for usage of Facility X, representing the ratio between the highest value of FX-VAR-FAC encountered simultaneously using Facility X (in accordance with its scheduled usage) and the value of FX-VAR-FAC itself. For example, if FX-VAR-FAC represents the number of students enrolled in the unit of achievement (S-ENR), and if half of the enrolled students may be found simultaneously using Facility X at some point in its scheduled usage, the FX-PK-FAC = .5.

3. FX-E-R-FAC: Facility X equipment requirements factor; the ratio of units of equipment (however measured) required per unit of FX-VAR-FAC simultaneously using Facility X.

4. E-R-FX: Total equipment requirements for Facility X, measured in the same units as those chosen for FX-E-R-FAC.

5. $/E-R-FX: Cost of purchase and installation per unit of equipment for Facility X.

NOTE: The effects of Factors 3 and 5 may be combined by use of a factor representing their product (perhaps denoted by FX-R-$-FAC) if there is no need to isolate $/E-R-FX as a variable for study.

6. E-R-FX-$: Total cost of purchase and installation of all equipment requirements for Facility X.

7. **E-FX-AMORT-FAC**: The annual amortization factor for the capital value of equipment for Facility X. If "i" is the interest rate on borrowed capital and LYR-E-FX is the lifetime (in years) of equipment for Facility X, the formula for E-FX-AMORT-FAC is:

$$\text{E-FX-AMORT-FAC} = \frac{1 + 1/2 \times i \times \text{LYR-E-FX}}{\text{LYR-E-FX}}$$

8. **E-FX-AV$/YR:** The annual capital costs of having the enabling resources represented by the equipment of Facility X available for use for one year.

9. **FX-H-R-FAC:** Facility X housing requirements factor, analogous to FX-E-R-FAC, but using such units of measure as square feet.

10. **H-R-FX:** Total housing requirements for Facility X measured in the same units as those chosen for FX-H-R-FAC.

11. **$/H-R-FX:** Cost of construction per unit of housing for Facility X.

12. **1+H-OH-FAC**: One (1.0) plus the housing overhead factor; the housing overhead factor is the ratio of the cost of indirectly used (support) housing and housing facilities (e.g., corridors, elevators) to the cost of directly used, function-supporting housing (e.g., offices, classrooms).

    NOTE: This factor is isolated in the COST-ED model since techniques of instruction (such as CAI) which use individualized scheduling instead of class scheduling may lead to a reduction in this factor.

13. **H-R-FX-$:** Analogous to E-R-FX-$, but for housing.

14. **H-FX-AMORT-FAC**: Annual housing depreciation factor, analogous to E-FX-AMORT-FAC.

15. **O&M-FAC**: The operations and maintenance factor for housing, the ratio of: those annual operating and maintenance costs which are invariable with usage made of the housing to the capital value of the housing.

NOTE: Operations and maintenance costs which are better considered variable with usage may be included in FX-OP$/U below:

16. **H-FX-AV$/YR**: Analogous to E-FX-AV$/YR.

17. **1-%FX-U**: One (1.0) minus percent usage of Facility X.

NOTE 1: The unit of usage for enabling resource is the product of an item such as the FX-VAR-FAC and time. Unless technical considerations interfere, the maximum possible usage of a facility per unit time (e.g., a year) is generally its capacity (i.e., FX-VAR-FAC x FX-PK-FAC) times the full unit of time (less allowances for custodial or maintenance work).

NOTE 2: Although the annual opportunity cost is isolated here, it is not deducted from the distribution of total costs actually incurred over total actual usage.

18. **FX-AV$/YR**: The total cost of having the enabling resources represented by Facility X available for use for one full year.

NOTE: As per the preceding note, this figure includes those charges separately identified as opportunity costs.

19. **FX-U/YR**: Total scheduled usage of Facility X per year, measured in terms of the product of FX-VAR-FAC and a measure of time, divided by one year.

NOTE: This factor may be dependent upon S-t/ACH, in which case special paths of calculation relating the two factors which are not shown in the model must be added to the flowchart.

20. FX-AV$/U: Total cost of having Facility X available per unit of usage made of it.

21. FX-OP$/U: Cost of operating resources consumed per unit of usage of Facility X.

NOTE: This item may include operations and maintenance costs considered variable on usage, as well as costs of other supplies consumed.

22. FX-U-$/U: Cost of using Facility X per unit of usage.

23. S-t/U: Student-time per unit usage.

NOTE 1: If the unit of usage is S-t, this factor is 1.0. If the time measure multiplied by FX-VAR-FAC to obtain the unit of usage is the same as that for S-t, this factor represents the average number of students who use the facility simultaneoulsy when this facility is in use.

NOTE 2: The unit of time used here must agree with that used for S-t in the Final Summarization Module.

24. FX-U-$/S-t: Cost of using Facility X per student per unit of time spent using the facility.

NOTE: Note 2 under S-t/U applies.

25. FX-OPP$/YR: The annual opportunity cost of not making fuller use of Facility X. This represents money which could be saved if facilities were used to capacity through rescheduling to minimize FX-PK-FAC. If this were done, total facilities requirements in units would fall proportionately to the reduction in FX-PK-FAC.

Linkages.

(7) FX-U-$/S-t may be used as, or as a component of, S-SPT-F-U-$/S-t, S-INST-F-U-$/S-t in the Final Summarization Module.

(8), (10) T-R from the Teacher Module or S-ENR from the Manpower Requirements Module may be used as FX-VAR-FAC's for appropriate types of facilities.

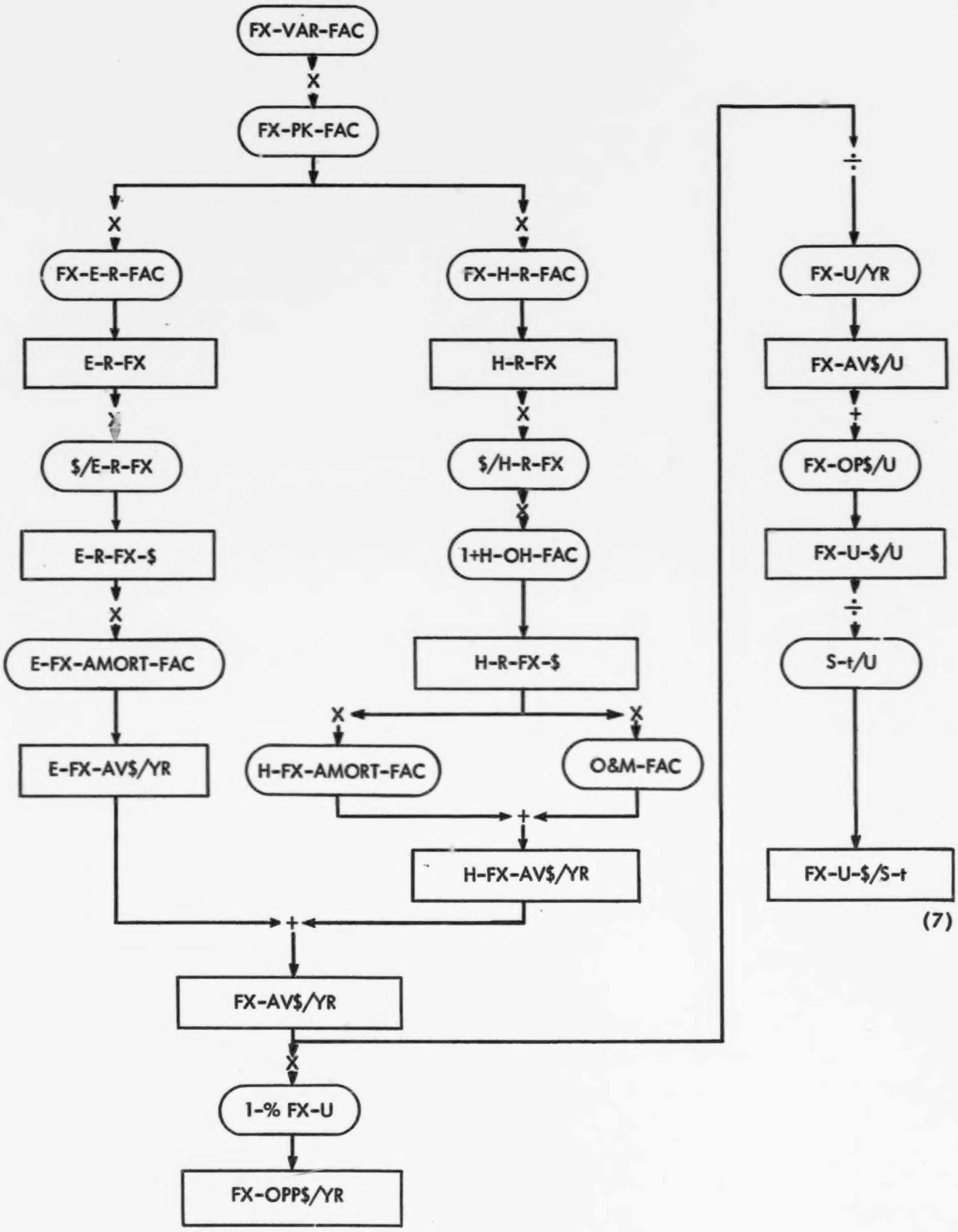

FX-VAR-FAC
X
FX-PK-FAC
X
X
FX-E-R-FAC
FX-H-R-FAC
E-R-FX
H-R-FX
X
X
$/E-R-FX
$/H-R-FX
X
E-R-FX-$
1+H-OH-FAC
X
E-FX-AMORT-FAC
H-R-FX-$
X
X
E-FX-AV$/YR
H-FX-AMORT-FAC
O&M-FAC
+
H-FX-AV$/YR
+
FX-AV$/YR
X
1-% FX-U
FX-OPP$/YR
÷
FX-U/YR
FX-AV$/U
+
FX-OP$/U
FX-U-$/U
÷
S-t/U
FX-U-$/S-t
(7)

Figure 7. Facilities Requirements Module

Student Opportunity Cost Module

Functions Performed.

- Provides a means for calculating the income from alternative employment foregone by a student while under full-time instruction.
- Provides a means for calculating any costs variable with student time which are not considered elsewhere in the model.

Types of Applications. May be used in any economic analysis where evaluation is being made of the effects of changes in S-t/ACH upon an economic statistic which includes both costs of instruction and costs (or revenues, depending on viewpoint) of alternative student activities. An example would be an evaluation of the effect on GNP of shortening the time required for an elementary and secondary education to 11 years. Another example would be an analysis of the costs of salesman training, where the opportunity costs may involve foregone sales revenue or profits to the employer.

Calculation Flowchart. (See Figure 8)

Cost Factors Used.

1. S-t/ACH: See Final Summarization Module.
2. 1 + % Sft: One (1.0) plus the percentage of student "free time", i.e., the percent of full-time employment time per week spent by the student in after-hours work as a part of the instructional process. (See Cost Factor 8)
3. S-PD-t: That part of S-t/ACH for which the student would receive pay for (or secure benefits from) full-time employment available as an alternative to receiving the instruction.
4. S-OPP$/t: The cost (revenue) which would accrue (to the student or any other financial entity) per unit of student time spent in alternative employment.
5. O-P/YR: The number of students graduating from the unit of achievement per year.

   NOTE: This is O-P/t with the time unit "t" converted to "year".

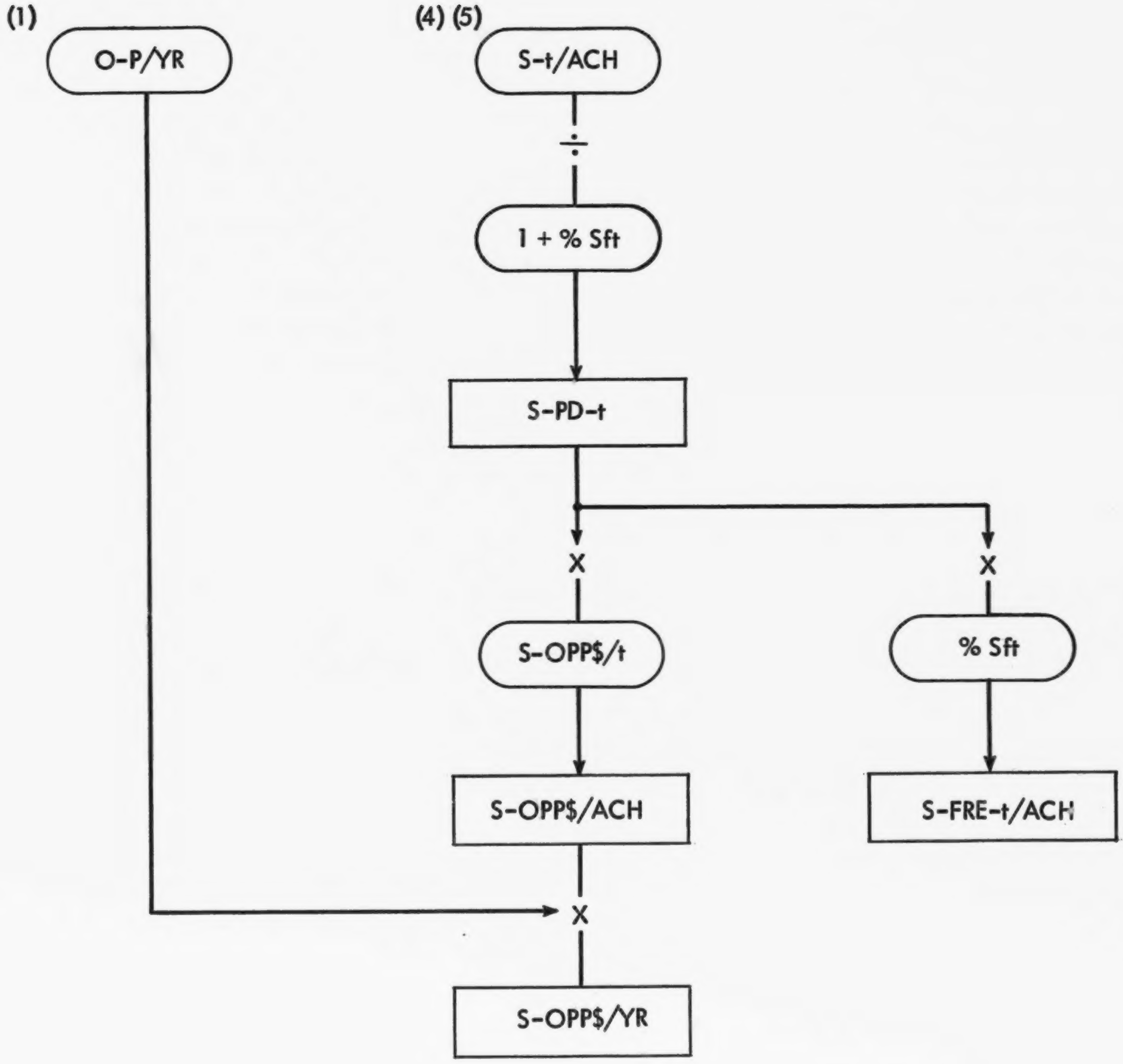

(1)
O-P/YR
(4) (5)
S-t/ACH
÷
1 + % Sft
S-PD-t
X
X
S-OPP$/t
% Sft
S-OPP$/ACH
S-FRE-t/ACH
X
S-OPP$/YR

Figure 8. Student Opportunity Cost Module

6. S-OPP$/ACH: The total student opportunity cost incurred per student completing the unit of achievement.

7. S-OPP$/YR: The total opportunity cost incurred for all students per year.

8. S-FRE-t/ACH: The amount of time spent by a student in the instructional process which is outside of that which would normally be available for alternative employment. This time represents a "free resource" contributed by the student to the instructional process, and may be thought of as "homework time."

Linkages.

(1) O-P/YR may be a time-converted form of O-P/t obtained from the Manpower Requirements Module.

(4) or (5) S-t/ACH (or S-t/ACH-*) is obtained from the Final Summarization Module, depending on whether the Attrition Module is used.

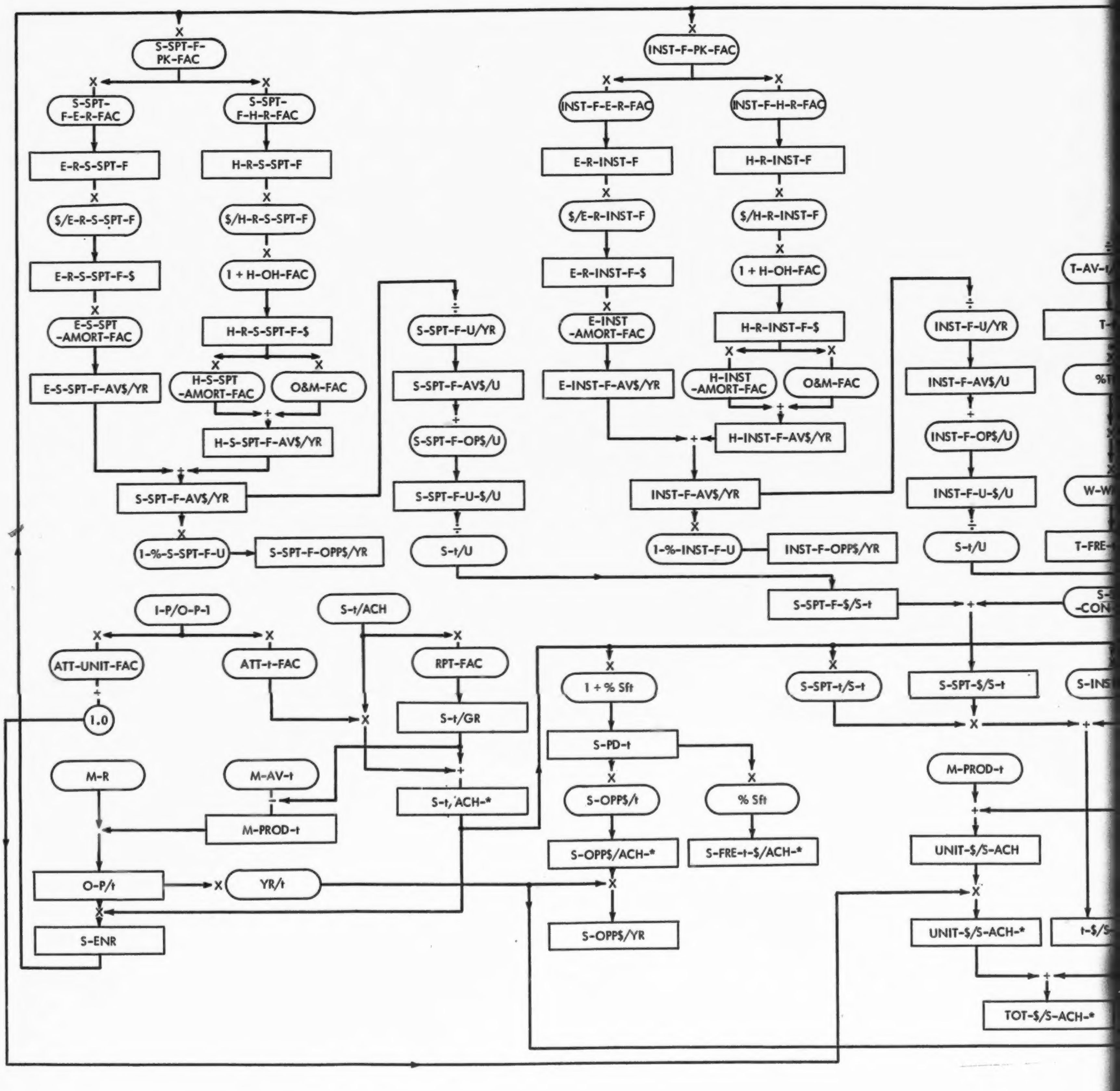
The Complete Model

Figure 9 is calculation flowchart illustrating a sample way of putting together the COST-ED Model which uses each module of the model.

Note that the Facility Utilization Module is used twice in this example, once for each function of the instructional process identified. Actually, if more than one type of facility is used in a given function (e.g., classrooms and laboratories), it may be desirable to assemble a separate instance of this module for each type. This would be done, for example, to add detail or allow certain types of trade-off analysis.

Similarly, the two major functions of student support instruction have not been further broken down into component subfunctions (e.g., administration, athletics, school transportation) in the example used. Additional functional breakouts could be simply by expanding the functions identified in the Final Summarization Module and adding appropriate Facilities Requirements or other modules to each function for detailed calculations.

The number of duplicative modules shown in Figure 9 is minimal to simplify graphical presentation. The detail within each module, however, is shown in full, to illustrate the full capabilities of the COST-ED Model. For any given application of the model, the user may wish to combine separately identified cost factors contiguous in the path of calculation to facilitate their estimation or use.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$/E-R-S-SPT-F
$/H-R-S-SPT-F
1 + H-OH-FAC
E-R-S-SPT-F-$
E-S-SPT -AMORT-FAC
H-R-S-SPT-F-$
E-S-SPT-F-AV$/YR
H-S-SPT -AMORT-FAC
O&M-FAC
H-S-SPT-F-AV$/YR
S-SPT-F-AV$/YR
1-%-S-SPT-F-U
S-SPT-F-OPP$/YR
S-SPT-F-U/YR
S-SPT-F-AV$/U
S-SPT-F-OP$/U
S-SPT-F-U-$/U
S-t/U
INST-F-PK-FAC
INST-F-E-R-FAC
INST-F-H-R-FAC
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H-R-INST-F-$
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H-INST -AMORT-FAC
O&M-FAC
E-INST-F-AV$/YR
H-INST-F-AV$/YR
INST-F-AV$/YR
1-%-INST-F-U
INST-F-OPP$/YR
INST-F-U/YR
INST-F-AV$/U
INST-F-OP$/U
INST-F-U-$/U
S-t/U
T-AV-
T-
%T
W-W
T-FRE-
S-SPT-F-$/S-t
S-
-CON
I-P/O-P-I
ATT-UNIT-FAC
ATT-t-FAC
1.0
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RPT-FAC
S-t/GR
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S-t, ACH-*
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S-OPP$/YR
S-SPT-t/S-t
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M-PROD-t
UNIT-$/S-ACH
UNIT-$/S-ACH-*
t-$/S
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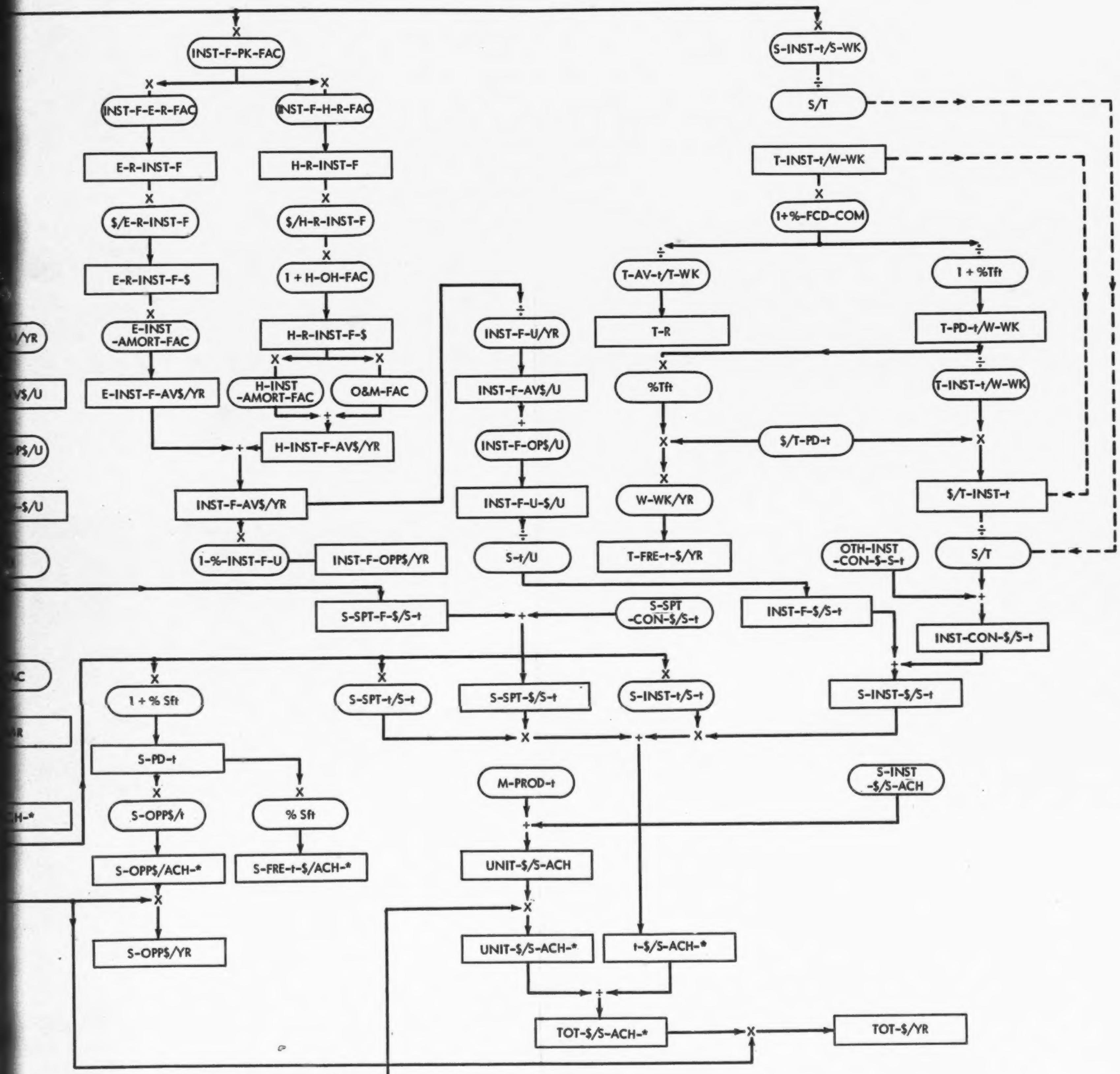
Figure 9. Sample Configuration of t


INST-F-PK-FAC
S-INST-t/S-WK
INST-F-E-R-FAC
INST-F-H-R-FAC
S/T
E-R-INST-F
H-R-INST-F
T-INST-t/W-WK
$/E-R-INST-F
$/H-R-INST-F
1+%-FCD-COM
E-R-INST-F-$
1 + H-OH-FAC
T-AV-t/T-WK
1 + %Tft
/YR
E-INST -AMORT-FAC
H-R-INST-F-$
INST-F-U/YR
T-R
T-PD-t/W-WK
V$/U
E-INST-F-AV$/YR
H-INST -AMORT-FAC
O&M-FAC
INST-F-AV$/U
%Tft
T-INST-t/W-WK
P$/U
H-INST-F-AV$/YR
INST-F-OP$/U
$/T-PD-t
-$/U
INST-F-AV$/YR
INST-F-U-$/U
W-WK/YR
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INST-F-$/S-t
INST-CON-$/S-t
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S-INST-t/S-t
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+

Figure 9. Sample Configuration of the COST-ED Model

No detailed specifications for how the COST-ED model may be used are offered here. How it is used depends upon the type of application, the purpose for which it is used, and the ability of the user to improvise. This last point is raised in recognition of the possibility of using the COST-ED model formulation as a basis for developing other models.

The description of the model modules in the preceding section, however, and the examples of their use which follow, should provide an adequate understanding of how the COST-ED model may be employed.

Justification of Increased Instructional Facilities

This section provides examples of how the COST-ED model may be applied to two different types of instructional situations and how it may be used for sensitivity and trade-off analysis. The examples of analysis are framed within the context of finding ways to justify increased instructional facilities costs through economies elsewhere in the instructional process. This framework was chosen for its immediate relevance to consideration of CAI as an instructional tool.

The New York City Day Academic High School

Figures 10 and 11 show cost data obtained from the New York City Board of Education which may be expressed in terms of the COST-ED model for purposes of economic analysis. Figure 12 illustrates a model for New York City's day academic high schools.

No attempt will be made here to describe in detail the cost analysis procedures used, although Figures 9 and 10 indicate what was done. Note however that:

- For the purpose of applying the model to an on-going activity, some of the cost factors were estimated backwards; that is, certain factors which the model used to calculate were obtained from available data, while some of the estimation factors in the model were calculated as links between two items of available data. The student-teacher ratio, for instance, was not specified a priori, but obtained as the ratio of actual students enrolled to actual teaching positions.

- Several groupings of cost factors in the COST-ED model were combined into aggregate factors. Thus the instructional facilities requirements cost factor shown (INST-F-R-$-FAC) combines what the model module shows separately as FX-E-R-FAC, FX-H-R-FAC, $/E-R-FX, $/H-R-FX, and 1 + H-OH-FAC.

- Both the Facilities Requirements and Teacher Modules were reorganized somewhat for this application. For purposes of simplification, for instance, equipment and housing were combined as a "facility", and the housing O&M Factor (O&M-FAC) applied not just to housing, but to the total.

- The unit of student time employed is the day (D), and costs of both functions are prorated over this unit. The unit of facility utilization chosen is the student-day (S-D). No attempt was made to distinguish between time spent using one or the other type of facilities within each day. Similarly, no attempt was made to count how many hours per day each teacher spends on different functions.

- Facilities utilization factors were arbitrarily chosen for illustrative purposes and are not supported by official statistics. An average of six hours per school day (plus 1/2 hour for custodial work) was used for classroom (instructional facilities) usage, and an average of 40 weeks per year for administrative and student support facilities, at eight hours per working day.

- The percent of teacher free time %Tft used was obtained from the National Education Association Research Report 1967 -R4, "The American Public-School Teacher", 1965-66, page 26, and is not necessarily accurate for New York City teachers.

- Total debt retirement expenditures per year were taken as an appropriate figure for facilities amortization, and include both principal repayments (corresponding to depreciation of facilities) and interest. Total New York City accumulated capital expenditure was taken as the measure of facilities cost, and was prorated among the different categories of schools (including day academic high schools) on the basis of current operating expenditures.

- It was arbitrarily estimated that 80% of the facilities were chargeable to the instruction function and 20% to student support.

- Student enrollment was estimated at 110% of average daily attendance.

It should be noted that the approximations made in developing this application of the COST-ED model may have prejudiced the accuracy of individual statistics somewhat, although the totals for the model compare with those reported by New York City. More extensive cost analysis would be required for higher detail accuracy.

Assuming the approximate validity of the statistics, however, the model formulation shows:

- Teachers contribute their free time worth over \$36 million per year to the instructional process. A change in instructional methodology which required the functions performed by teachers after hours to be performed during the day would require the performance of these functions to be paid for.

- Over \$32 million a year is spent supporting facilities not in use.

- Almost all costs were incurred on a time dependent basis; hence, there would be no large items of cost unaffected by changes in the time required to complete the unit of achievement (one grade level).

- About one-quarter of total costs are incurred for student support, not for achievement-producing instruction (this figure is highly dependent on the arbitrary assumptions made).

The statistics provided in Figure 10 will now be used as the basis for sensitivity and trade-off analysis to examine how higher instructional facilities costs might be justified.

Sensitivity analysis is the process of answering the question: If Factor A is changed by so much, by how much is Factor B affected?

A first example is the problem of determining how sensitive instructional facilities costs per student day (INST-F-U-\$/S-D) are to the instructional facilities peak factor (INST-F-PK-FAC), which is one parameter of the scheduling employed for these facilities.

- Tracing the path of calculation between the two factors on Figure 12, it is seen that:

  INST-F-U-\$/S-D = \$.229 x INST-F-PK-FAC + \$.007

  and, for the actual value of INST-F-PK-FAC = 1.0,

  INST-F-U-\$/S-D = \$.236.

	Salaries	Other Objects	Total
Total Instruction Proper	$510,131	$ 20,328	$530,459
Physical Maintenance of Plant	$ 8,624	$ 12,357	$ 20,981
Physical Operation of Plant			
Custodial Service	40,354	529	40,833
Fuel	-	3,012	3,012
Utilities	-	7,351	7,351
Total	$ 40,354	$ 10,892	$ 51,246
Administration			
Personnel & Teacher Training	3,168	100	3,268
All Other	25,619	5,083	30,702
Total	$ 28,787	$ 5,183	$ 33,970
Auxiliary Charges			
Transportation of Pupils	225	41,433	41,658
Health Service	8,585	-	8,585
Other (General)	3,302	726	4,028
Other (Inapplicable*)	34,985	10,393	45,378
Total	$ 47,097	$ 52,552	$ 99,649
Fixed Charges			
Salary Overhead	912	139,070	139,982
Other	-	1,156	1,156
Total	$ 912	$140,226	$141,138
Debt Service	-	$113,165	$113,165
TOTAL	$635,905	$354,704	$990,609

* Inapplicable for proration to day academic high schools.

Source: Board of Education, City School District of New York, Annual Financial and Statistical Report, 1965 - 1966.

Figure 10. Annual Costs of New York City School System: 1965 - 1966

- It may be concluded that, for values near its present one, INST-F-PK-FAC is directly proportionate to about 97% of the value of INST-F-U-$/S-D; this means that a given small fractional change in INST-F-PK-FAC will lead to 97% of the same fractional change in INST-F-U-$/S-D.

- Thus instructional facilities utilization costs per student day are highly sensitive to their peak usage factor.

A second example would be to determine how sensitive total instructional costs per unit achievement were to changes in instructional facilities utilization costs per student-day.

- Tracing down the path of calculation from INST-F-U-$/S-D toward TOT-$/S-ACH, we see that:

    - INST-F-U-$/S-D is 20% of INST-$/S-D;

    - INST-$/S-D is 75% of total cost per student-day;

    - Total costs per student-day, multiplied by total student time per unit achievement, represent 100% of t-$/S-ACH;

    - t-$/S-ACH is 99% of TOT-$/S-ACH

- It may be concluded that a small change in INST-F-U-$/S-D is directly proportionate to only 20% x 75% x 99% or slightly under 15% of TOT-$/S-ACH. This means that, for a slight change in INST-F-U-$/S-D, the percentage change in TOT-$/S-ACH will be only 15% as great.

- Thus total costs per unit of student achivement are not very sensitive to changes in the facilities utilization cost factor.

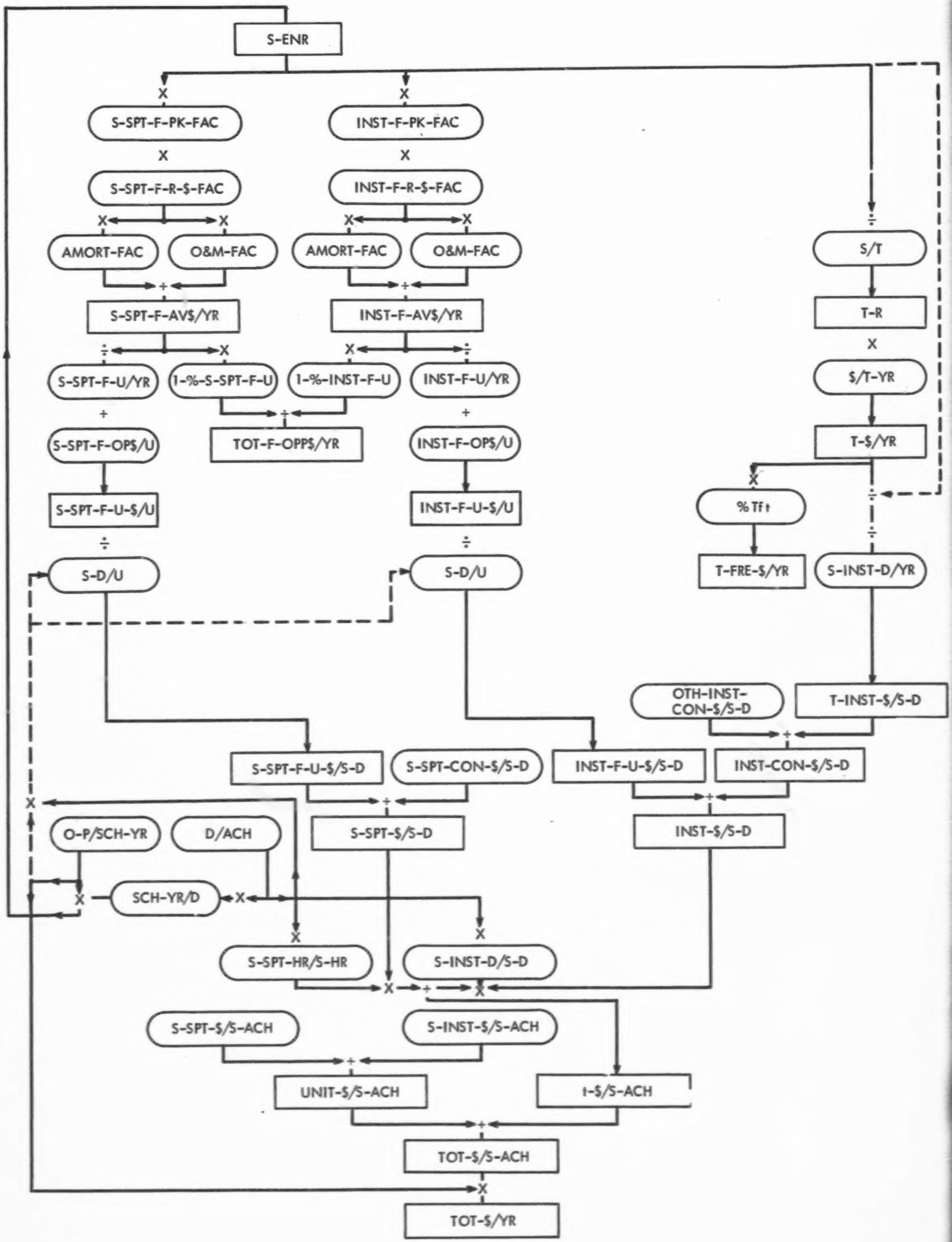
New York City Reported Statistics for Day Academic High Schools		Pro-Ration of Reported Statistics	Re-Allocation of Overhead Items	T
Instruction Proper				
Instructional Salaries	$107,942		$134,564	$1
Textbooks	1,716		1,716	
Library Books	432		432	
Educational Supplies & Equip.	1,418		1,418	
Other	1,132		1,132	
Maintenance	3,408		3,742	
Operation	8,268	-		
Custodial Services & Fuel		$7,088	8,638	
Utilities		1,180	1,180	
Administration	6,542	-		
Teacher Training		620	-	
Other		5,922	7,102	
Transportation	17,029		17,049	
Other Auxiliary Charges	3,238		3,978	
Fixed Charges	30,126	-		
Salary Overhead		29,826	-	
Other		300	300	
Total Current Charges	$181,251		$181,251	
Debt Service		25,000	25,000	
Total Annual Costs			$206,251	

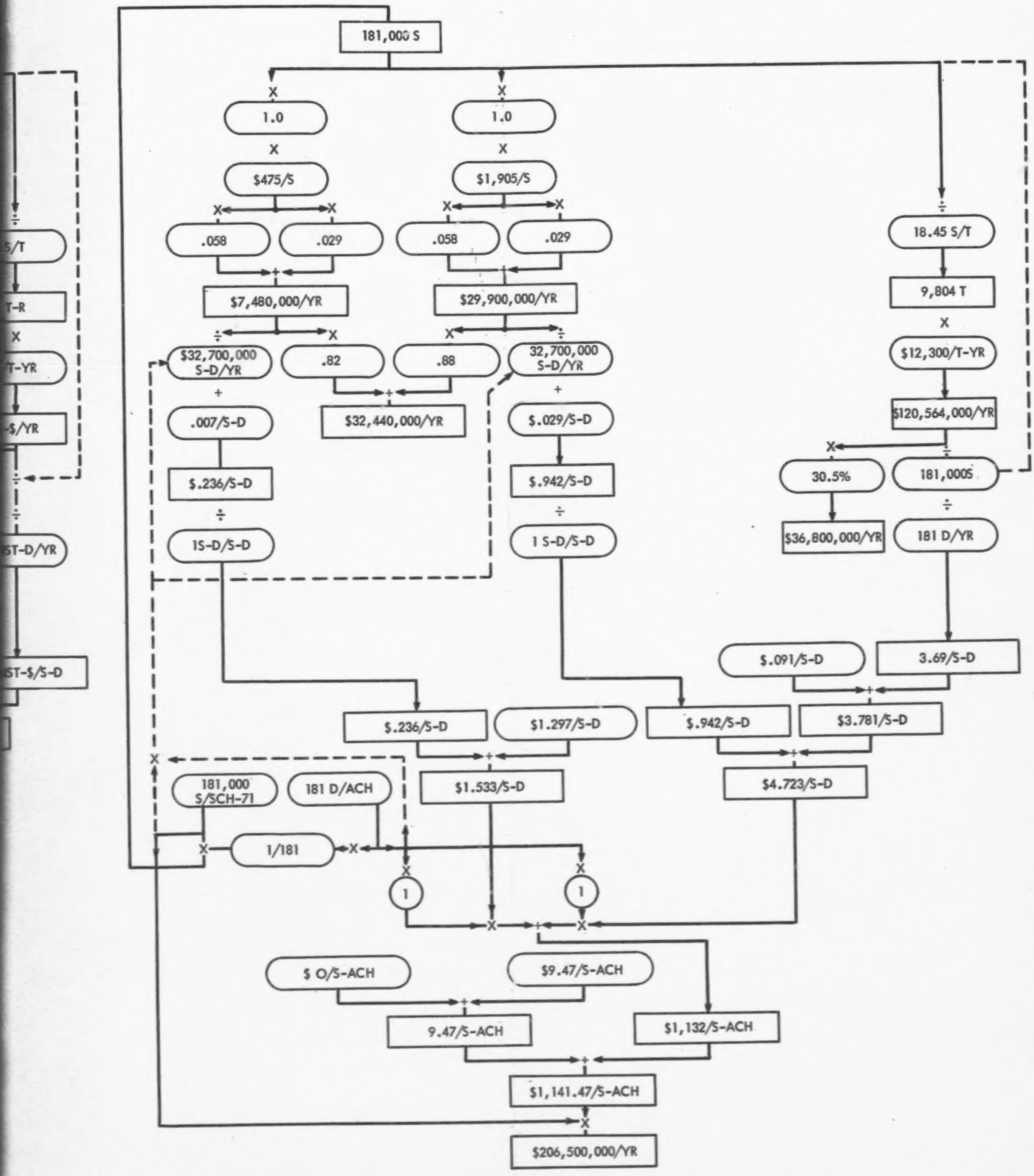
Sources: Board of Education, City School District of the City of New York: Annual Financial and Statistical Report, 1965 - 1966; and, Budget Estimate for 1968 - 1969, dated December 11, 1967.

	RE-ALLOCATION TO ANNUALIZED COST-ED MODEL COST FACTORS							
	INSTRUCTION FUNCTION					STUDENT SUPPORT FUNCTION		
cation of ad Items	T-$/Yr.	OTH-INST-CON-$/Yr.	INST-F-AV$/Yr.	INST-F-OP$/Yr.	S-INST-$/ACH/Yr	S-SPT-CON-$/Yr.	S-SPT-F-AV$/Yr.	S-SPT-F-OP$/Yr.
564	$120, 564					$14, 000		
716					$1, 716			
432		$ 432						
418		1,418						
132		1,132						
742			$ 3,000				$ 742	
638			6,900				1,738	
180				$940				$240
-								
,102						7,102		
,049						17,049		
,978						3,978		
-								
300							300	
,251								
,000			20,000				5,000	
,251	$120, 564	$2,982	$29,900	$940	$1, 716	$42,429	$7,780	$240

k: Annual
mate for

Figure 11. Conversion of Cost Data From Reported to COST-ED Model Format


S-ENR
S-SPT-F-PK-FAC
INST-F-PK-FAC
S-SPT-F-R-$-FAC
INST-F-R-$-FAC
AMORT-FAC
O&M-FAC
AMORT-FAC
O&M-FAC
S/T
S-SPT-F-AV$/YR
INST-F-AV$/YR
T-R
S-SPT-F-U/YR
1-%-S-SPT-F-U
1-%-INST-F-U
INST-F-U/YR
$/T-YR
S-SPT-F-OP$/U
TOT-F-OPP$/YR
INST-F-OP$/U
T-$/YR
S-SPT-F-U-$/U
INST-F-U-$/U
%Tft
S-D/U
S-D/U
T-FRE-$/YR
S-INST-D/YR
OTH-INST-CON-$/S-D
T-INST-$/S-D
S-SPT-F-U-$/S-D
S-SPT-CON-$/S-D
INST-F-U-$/S-D
INST-CON-$/S-D
O-P/SCH-YR
D/ACH
S-SPT-$/S-D
INST-$/S-D
SCH-YR/D
S-SPT-HR/S-HR
S-INST-D/S-D
S-SPT-$/S-ACH
S-INST-$/S-ACH
UNIT-$/S-ACH
I-$/S-ACH
TOT-$/S-ACH
TOT-$/YR


181,000 S
X
1.0
X
$475/S
X
X
.058
.029
+
$7,480,000/YR
÷
X
$32,700,000 S-D/YR
.82
+
.007/S-D
$.236/S-D
÷
1S-D/S-D
X
1.0
X
$1,905/S
X
X
.058
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+
$29,900,000/YR
X
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.88
32,700,000 S-D/YR
+
$32,440,000/YR
$.029/S-D
$.942/S-D
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1 S-D/S-D
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18.45 S/T
9,804 T
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$12,300/T-YR
$120,564,000/YR
X
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30.5%
181,000S
$36,800,000/YR
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181 D/YR
$.091/S-D
3.69/S-D
+
$3.781/S-D
$.942/S-D
+
$4.723/S-D
$.236/S-D
$1.297/S-D
+
$1.533/S-D
X
181,000 S/SCH-71
181 D/ACH
X
1/181
X
X
1
X
1
X
+
X
$ O/S-ACH
$9.47/S-ACH
+
9.47/S-ACH
$1,132/S-ACH
+
$1,141.47/S-ACH
X
$206,500,000/YR
÷
S/T
T-R
X
T-YR
-$/YR
÷
÷
ST-D/YR
ST-$/S-D

Figure 12. COST-ED Model for the New York City Day Academic High School

The above two examples point to two immediate conclusions which can be drawn concerning justification of large-percentage increases in instructional facilities costs in the New York City day academic high school.

- First, they will have a much smaller than proportionate impact on total costs; and, secondly,
- A powerful way of reducing instructional facilities costs is to schedule their use in such a way as to flatten peak requirements.

Trade-Off Analysis

The second conclusion above leads smoothly into an example of trade-off analysis, if we ask the question

> Holding INST-F-U-\$/S-D and all other contributing factors fixed, by how much will a given reduction in the peak factor INST-F-PK-FAC allow an increase in the facilities cost factor INST-F-R-\$-FAC (which represents total investment in instructional facilities per student capacity)?

- Keeping the two factors to be traded off in symbolic form, the path of calculation in which both they and INST-F-U-\$/S-D appear leads to the formula:

$$\$.942 = \$.029 + 181{,}000 \times \text{INST-F-PK-FAC} \times$$

$$\times\ \text{INST-F-R-\$-FAC} \times (.058 + 029) \div$$

$$\div\ 32{,}700{,}000$$

or

$$\$1905 - \text{INST-F-FR-FAC} \times \text{INST-F-R-\$-FAC}$$

- This relationship is plotted in Figure 13(A), and the relationship between percentage of change in each factor plotted in Figure 13(B).

In considering the installation of a CAI system, one of the easiest factors to use for purposes of cost estimation is the dollar investment per student served, the equivalent of INST-F-R-$-FAC. For purposes of illustrating other trade-off analyses, the CAI version of this factor, CAI-R-$-FAC, will be traded off against four possible sources of savings which may result from use of CAI.

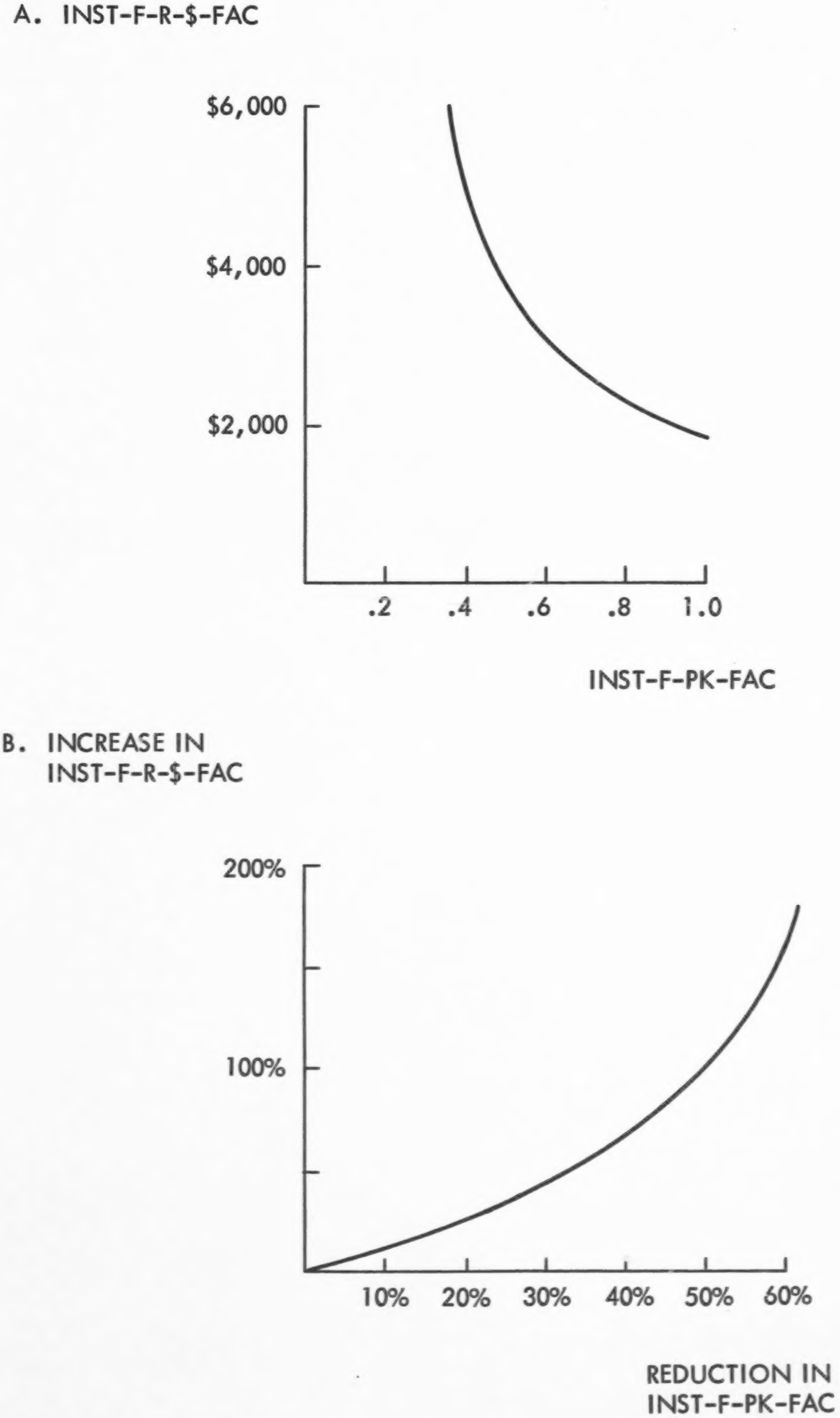


Figure 13. Example of Trade-Off Analysis: Instructional Facilities Cost vs. Peak Usage

- Decreases in the level of required teacher qualifications, as represented by decreases (or avoidance of future increases) in teacher cost per year \$/T-YR.

- Increases in the allowable student:teacher ratio, S/T;

- Decreases in administrative costs per student day, estimated from the figures in the S-SPT-CON-\$/YR column of Figure 11 at 16.7% of S-SPT-\$/S-D; and,

- Decrease in time per unit achievement D/ACH.

In order to make this analysis as realistic as possible, a new Facilities Requirements Module will be added to the model to represent CAI facilities. This is done to allow use of the higher O&M-FAC that CAI facilities would be expected to have as compared with classroom facilities. With proper elimination of needless detail and the addition of the CAI Facilities Requirements Module. a revised model of the New York City day academic high school would look like Figure 14. Note that amortization, O&M, and operating expenses for the CAI model module are arbitrarily assumed as being twice as high as the equivalent figures for conventional instructional facilities. Also, note that the CAI costs are considered to be completely additive to current costs without replacing (i.e., reducing) them.

Performance of the trade-off analyses between CAI investment cost per student and the four factors noted above leads to the graphs shown combined in Figure 15. Use of actual cost data for a specific CAI system would change the numerical scales but not the basic form of the relationships shown.

Figure 15 points outs that

- CAI investment does not begin to be justified at all until after the per-unit usage operating costs CAI-OP\$/S-D are compensated by savings elsewhere.

- Savings in D/ACH, time per unit achievement, is the strongest way to justify increased instructional facilities investment for CAI.

- Savings in \$/T-YR, average annual teacher costs, is the second strongest source of justification for CAI equipment investment, and is about half as fruitful per percent saved as time per unit achievement (for small values of percent saved).

- Increases in S/T, the student:teacher ratio, are a slightly less productive source of justification for CAI equipment investment than savings in teacher costs.

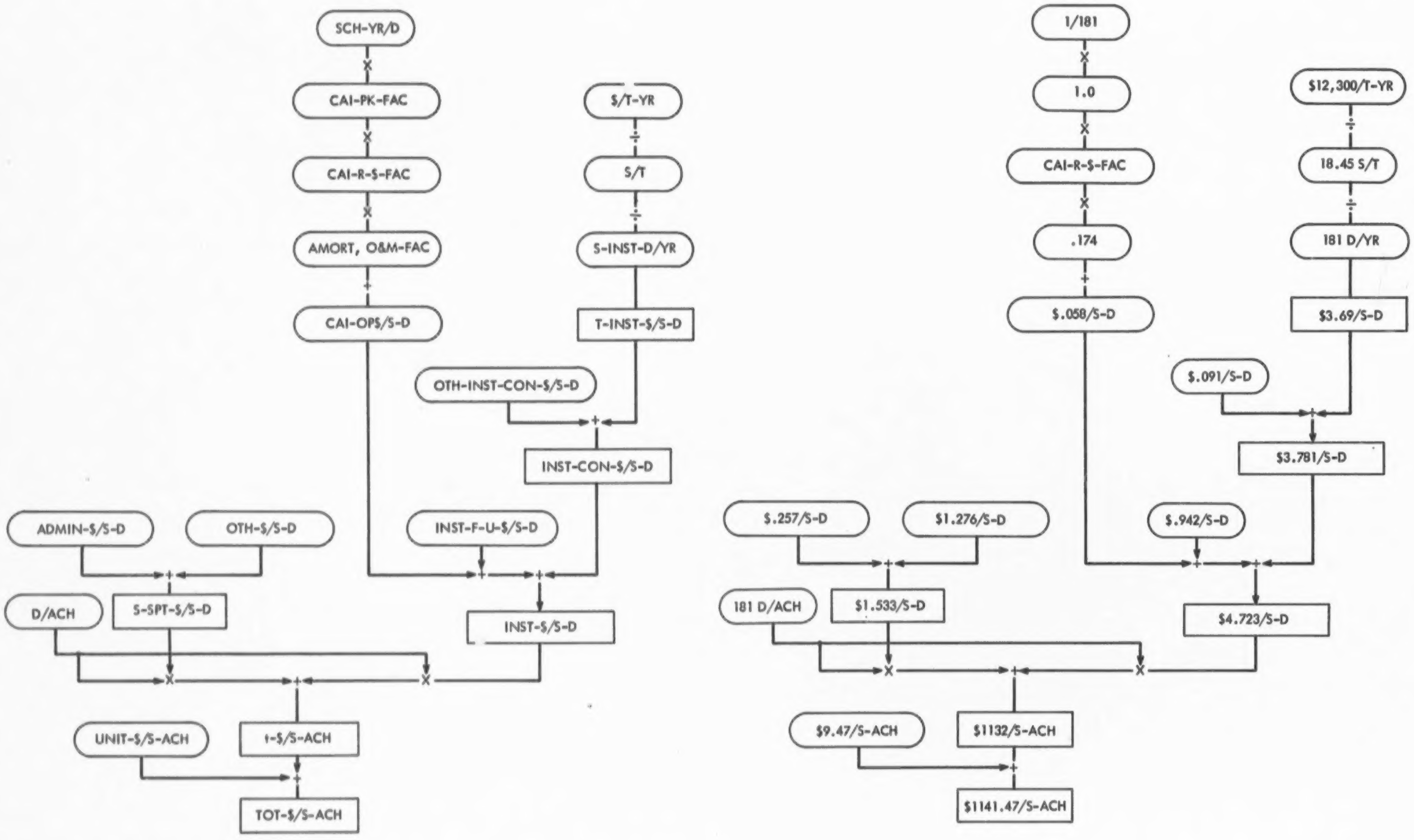

SCH-YR/D
CAI-PK-FAC
CAI-R-$-FAC
AMORT, O&M-FAC
CAI-OP$/S-D
$/T-YR
$/T
S-INST-D/YR
T-INST-$/S-D
OTH-INST-CON-$/S-D
INST-CON-$/S-D
INST-F-U-$/S-D
INST-$/S-D
ADMIN-$/S-D
OTH-$/S-D
D/ACH
S-SPT-$/S-D
I-$/S-ACH
UNIT-$/S-ACH
TOT-$/S-ACH
1/181
1.0
CAI-R-$-FAC
.174
$.058/S-D
$12,300/T-YR
18.45 S/T
181 D/YR
$3.69/S-D
$.091/S-D
$3.781/S-D
$.942/S-D
$4.723/S-D
$.257/S-D
$1.276/S-D
181 D/ACH
$1.533/S-D
$9.47/S-ACH
$1132/S-ACH
$1141.47/S-ACH

Figure 14. Simplified COST-ED Model for the New York City Day Academic High School

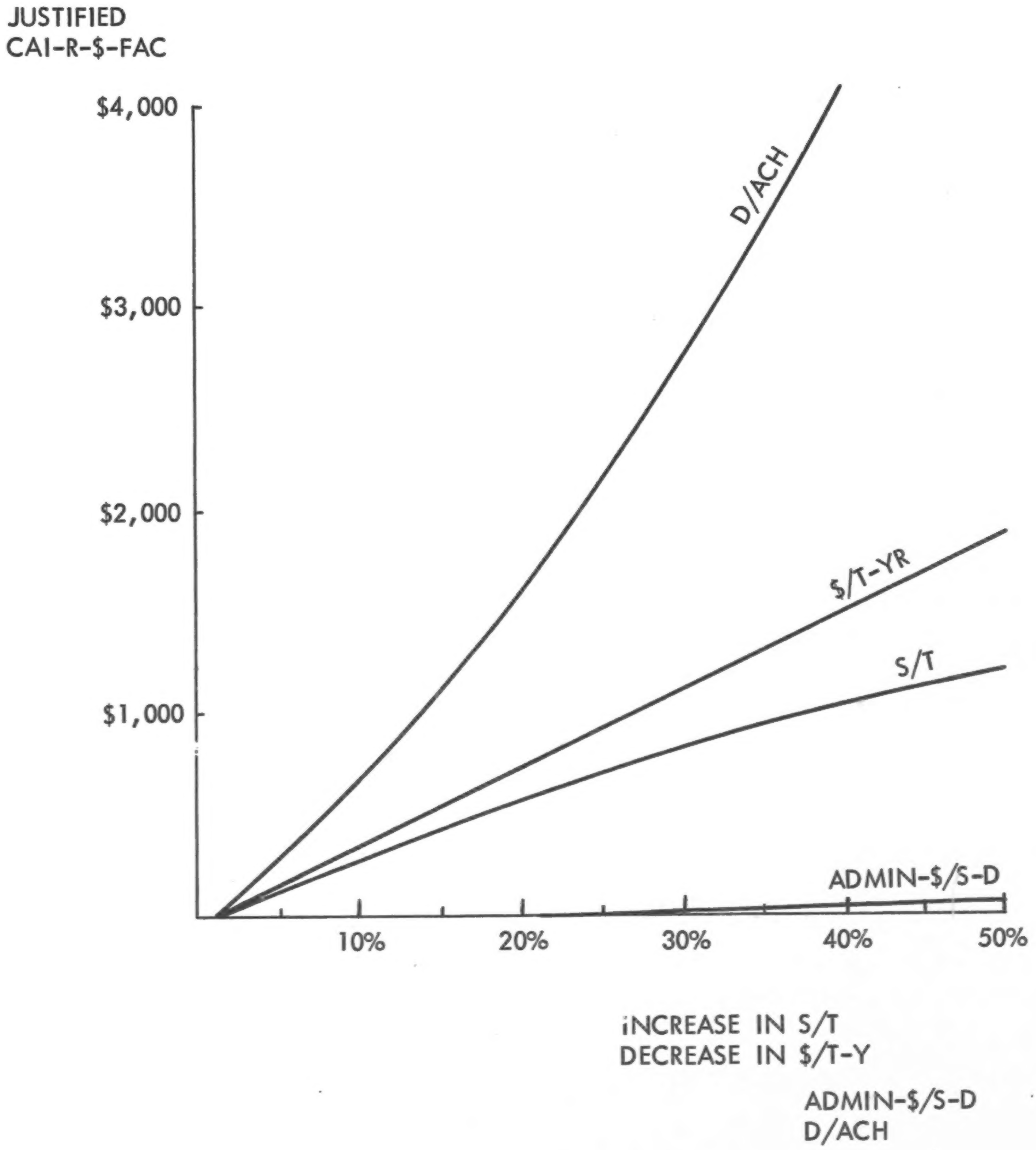


Figure 15. Four Trade-Offs to Justify CAI Investment in the New York City Day Academic High School

- Administration cost savings produce negligible justification for CAI investment.

Savings from a combination of these sources would obviously increase total CAI investment justified beyond that shown for any one line in Figure 15. The total investment justified from a combination of these sources, however, is not necessarily the sum of the individual justifications. The easiest way to find the value of investment justified from a combination of sources is simply to convert the relevant portion of the calculation flowchart (e.g., Figure 14) to an algebraic formula, insert the reduced values of the factors being examined, and solve for CAI-R-$-FAC. As an example, a 10% reduction in average annual teacher costs, combined with a 20% savings in time, leads to a total CAI investment justified of about $1,860 per student enrolled.

To further analyze the alternatives available for justifying CAI investment, we may use the results shown in Figure 13, which show the sensitivity of the facilities cost factor to their peak factor. This chart may be read to show that if use of the CAI facilities may be so scheduled that no more than 50% of all students enrolled ever need to use them simultaneously, the original investment per student enrolled which is justified may be doubled.

Concluding this application of the COST-ED model to the question of justifying investment in CAI facilities in New York's day academic high schools, it may be asserted that there would be

- A reduction in time to learn of 20%;
- A reduction in average teacher costs of 10%;
- A scheduling plan for peak usage of CAI facilities by no more than 50% of total students enrolled; and
- Justification for an investment in CAI facilities of about $3,720 per student enrolled.

It is up to the designers of the CAI equipment, the CAI curriculum materials, and the organizational and administrative structures for employing CAI to determine whether such reductions and savings as outlined above are within the technical and psychological capabilities of the CAI instructional medium. The COST-ED model has provided only a simple framework for analysis of the economic factors involved.

Military Technician Training

The example of the New York City academic high school provided some insight into the economic considerations relevant to increasing the investment in enabling resources used in education. It would be misleading, however, to consider the ball park estimates of economic trade-offs noted in the last section typical of all instructional situations.

In fact, instructional activities vary a great deal from situation to situation. Presented in this section is a coarse model of the particular kind of military training given to the growing armada of technicians and equipment repairmen. The specific cost factors used are to be considered of the same order of magnitude as would be encountered in a military training situation for enlisted men, but are not meant to be exact measures of any specific case. The cost factors used for CAI are rounded-off equivalents to those used in the description of the New York City academic high school.

Figure 16 illustrates the COST-ED model tailored to the military training situation. Note that the Manpower Requirements Module and the Attrition Module are used in this formulation because their application to this type of training is most appropriate. Also, a version of the Student Opportunity Cost Module has been used. A peak factor for the CAI equipment of only .4 is employed in recognition of a greater facility in the military for scheduling double shifts of students than would be the case in elementary or secondary education.

Military training is the paragon of the situation in which fixed manpower requirements and periods of manpower availability determine the volume of training to be conducted. A pool of manpower with certain qualifications must be kept in the field. To replace men lost from this pool through expiration of their term of service, a second pool of men must be kept in the "training pipeline." The size of the training pipeline (otherwise called the in-training load, and denoted by S-ENR in the COST-ED model) depends upon those factors outlined in the Manpower Requirements and Attrition Modules.

Should training time be reduced without a change in the periods of manpower availability, the size of the in-training load would fall. More time per man would be available for field duty, reducing field turnover rates and thereby the training output required per year. Man-years cut from the training pipeline need not be used elsewhere in the military, as this economy may be made without reducing support of field personnel. Hence the man-years saved represent draftees who need not be drafted, and who could earn civilian wages instead of the reduced military pay and compensation. The difference between the civilian and military incomes of all persons in the training pipeline represents an opportunity cost to them (and to the nation), and this is the figure estimated by the Opportunity Cost Module in Figure 16. In the current example, assuming a $25/week differential between civilian and military compensation for the men involved, this figure amounts to $1,405,000 a year for the entire in-training load.

The example of the New York City academic high school illustrated several of the trade-offs which may be calculated against an investment in CAI facilities. For the military example, only the trade-off against student time will be duplicated, but additional trade-offs against key student flow parameters will be made.

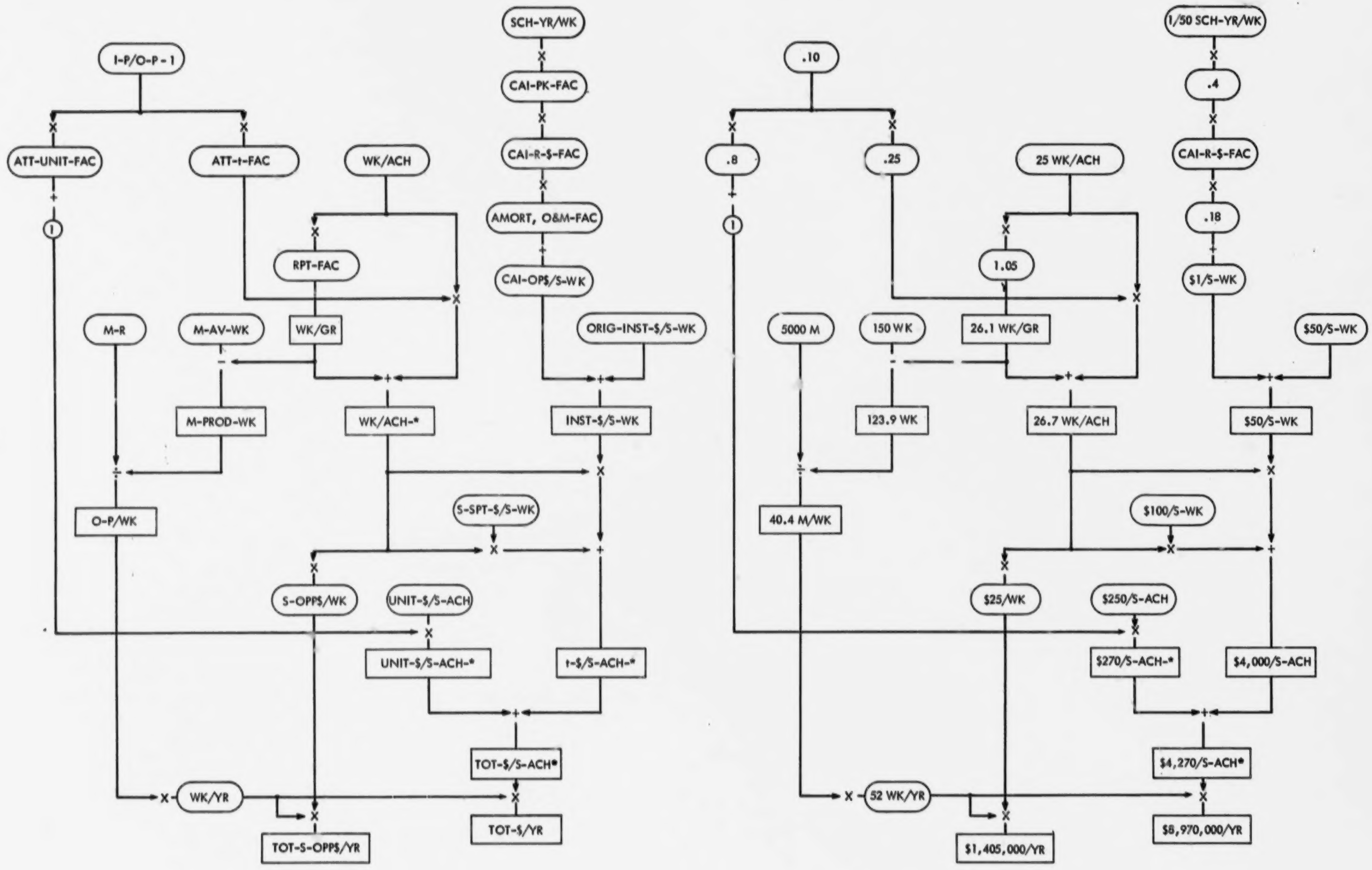

I-P/O-P - 1
ATT-UNIT-FAC
ATT-t-FAC
WK/ACH
SCH-YR/WK
CAI-PK-FAC
CAI-R-$-FAC
AMORT, O&M-FAC
CAI-OP$/S-WK
ORIG-INST-$/S-WK
1
RPT-FAC
M-R
M-AV-WK
WK/GR
M-PROD-WK
WK/ACH-*
INST-$/S-WK
O-P/WK
S-SPT-$/S-WK
S-OPP$/WK
UNIT-$/S-ACH
UNIT-$/S-ACH-*
t-$/S-ACH-*
TOT-$/S-ACH*
WK/YR
TOT-S-OPP$/YR
TOT-$/YR
.10
1/50 SCH-YR/WK
.4
CAI-R-$-FAC
.18
$1/S-WK
.8
.25
25 WK/ACH
1
1.05
5000 M
150 WK
26.1 WK/GR
$50/S-WK
123.9 WK
26.7 WK/ACH
$50/S-WK
40.4 M/WK
$100/S-WK
$25/WK
$250/S-ACH
$270/S-ACH-*
$4,000/S-ACH
$4,270/S-ACH*
52 WK/YR
$1,405,000/YR
$8,970,000/YR
x
+
-
÷

Figure 16. COST-ED Model for a Military Training Situation

Figure 17 plots the investment in CAI facilities justified by a given percentage decrease in WK/ACH-*, the attrition and recycle-corrected time per unit achievement. This plot is analogous to the D/ACH line in Figure 15, and is based on holding the total cost per unit achievement (course graduate) constant. The difference between the two figures may be traced to the following factors by simple visual inspection of the model:

- Higher original time-dependent costs of the instructional process in the military; and
- Lower peak facilities utilization factor scheduable in the military.

In the example used, the first factor increases investment per unit student capacity for CAI facilities by eight times over the value for the New York City high school. The second factor added a further multiplicative increase of 2.5 times.

The most important component of the most significant factor is the higher student support cost per unit time in the military as compared with the secondary school. This arises from the fact that military students are paid, fed, housed, clothed, and drilled while in school, while the equivalent costs for civilian students are borne by them themselves or by their parents. (Should it prove desirable, recognition of such costs as these in the civilian case may be made through redefinition of the student support cost factors or adaptation of the Student Opportunity Cost Module.)

This finding illustrates the fallacy of comparing costs of different educational techniques on the basis of direct instruction costs alone. Such comparison is valid only if there is no difference in time requirements for facilities scheduling between the two techniques.

The effects of reducing student attrition or recycling time may also be read off the graph in Figure 17, if the relatively minor component of changes in student unit costs is disregarded. Since one of the effects of attrition is to increase net student time per unit student achievement, a reduction in attrition may be considered approximately equivalent to a reduction in net time per unit achievement. Observing the sensitivities of one factor on another as shown in the Attrition Module section of Figure 16 and using the relationship plotted in Figure 17, it may be estimated that:

- The complete elimination of attrition, with no change in the cycle factor, will have only a negligible effect on facilities investment justified. This can be seen from observation of the Attrition Module on the right hand portion of Figure 16.

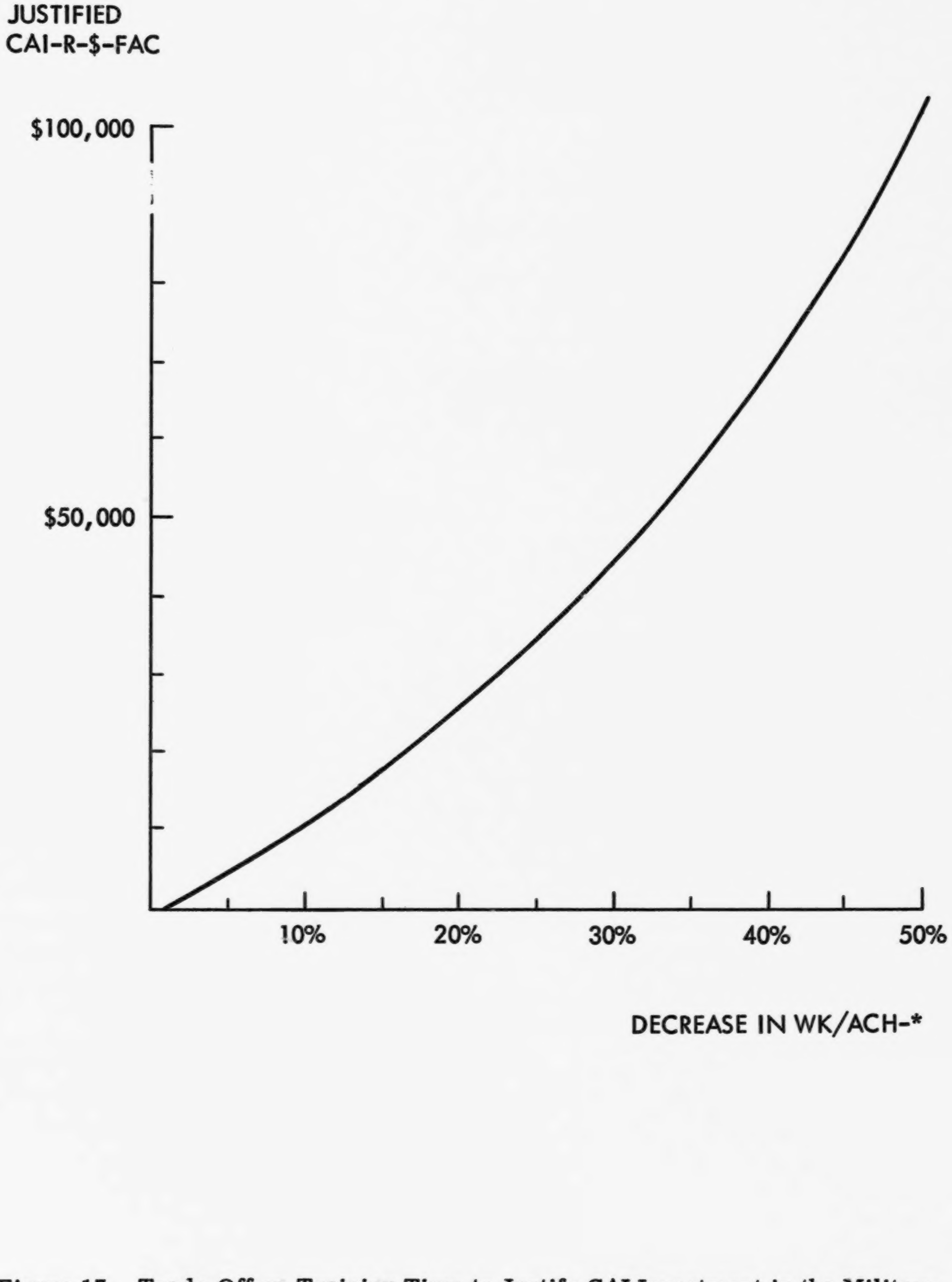


Figure 17. Trade-Off on Training Time to Justify CAI Investment in the Military

- The complete elimination of recycling will have largely the same effect as a 5% reduction in training time. This would justify $5,000 of investment in CAI facilities per unit student capacity.

Up to this point, trade-off analysis in this example has been performed holding cost per unit achievement (i.e., per graduate) constant. Actually, this is not the proper basis for strict economic justification of investment in instructional facilities. The proper basis to use is the total training cost per year TOT-$/YR needed to support the manpower requirements in the field. It is this figure which actually appears on the accounts.

Performing a trade-off analysis between WK/ACH, the normal training time, and the investment per unit capacity in CAI facilities CAI-R-$-FAC with total training costs per year TOT-$/YR constant, the upper line in Figure 18 is produced. For purposes of comparison, the plot of Figure 17 is reproduced below it.

Note that an additional 20% of investment in CAI facilities is shown as justified when total training costs are used than when only costs per unit achievement are used as the constant in the trade-off analysis. This is due solely to the reduced requirements for training which result from getting the trained soldier out into the field faster and for a longer period of time by reducing training time.

In general, the percentage increase shown by this trade-off over that shown by trade-off on unit achievement costs is given by the formula:

$$\frac{\text{M-AV-t}}{\text{M-PROD-t}} - 1$$

where values of these factors prior to changes in training time are used. The smaller the original percentage of a man's available time spent in productive service (or the higher his original percent of time available spent in training), the larger this effect will be.

One other final statistic which may be of interest is the change in student opportunity cost that would be occasioned by a reduction in training time. As an example, a 20% reduction in training time leads to a 23.8% reduction in student opportunity costs, or $335,000 per year added to the national income in the pockets of 237 men who enjoy civilian instead of military status. This formula does not take unit costs into account and is an understatement of the true increase to the extent that unit costs are high.

Cost Considerations for CAI

Computer assisted instruction is an educational medium which can be described within the context of the COST-ED model. Illustrations of the treatment of CAI for economic analysis were presented in the examples of the New York City High School and Military Technician Training.

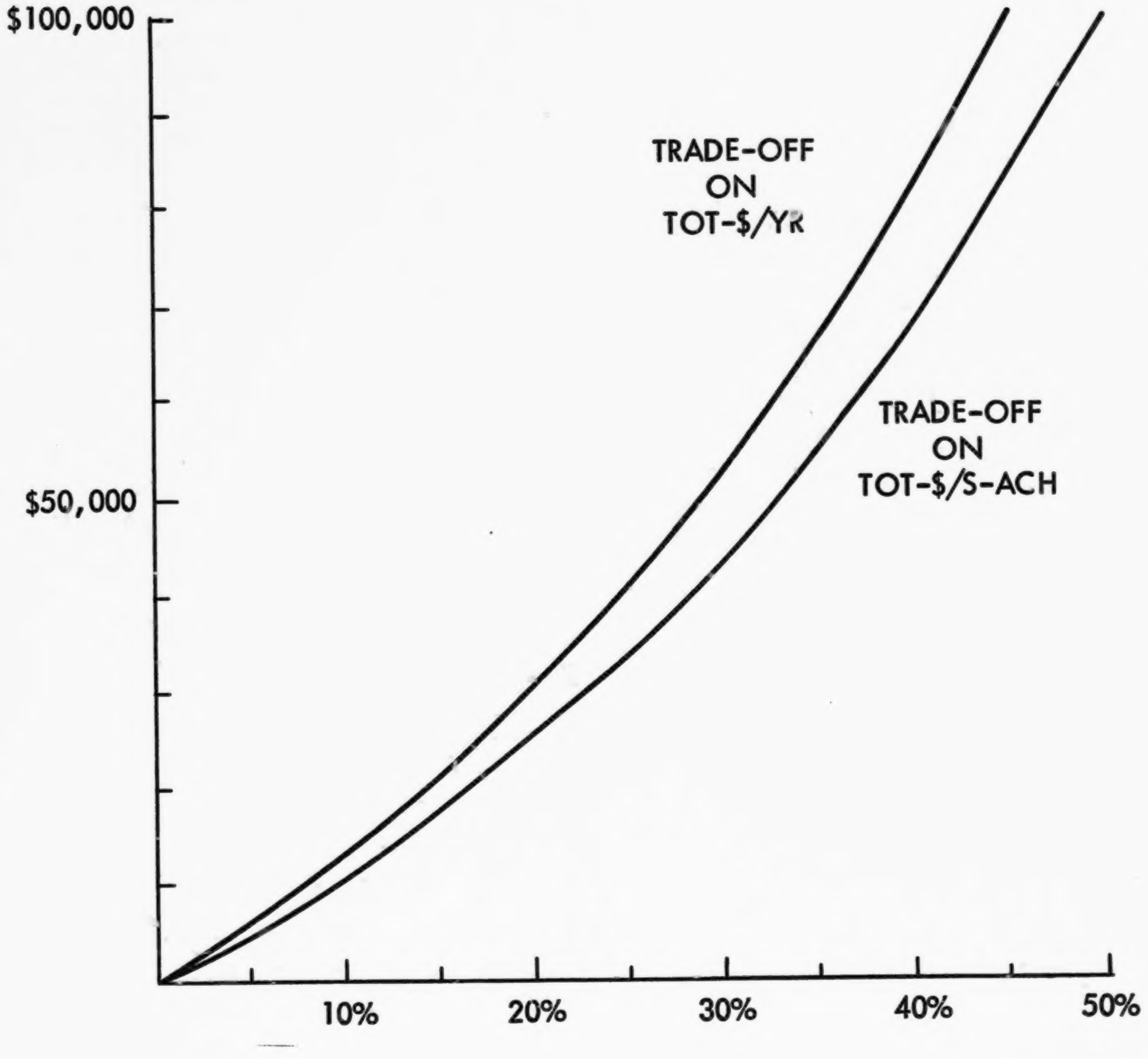


Figure 18. Compairson of Trade-Off Alternatives

One of the major differences between CAI and more traditional methods of instruction is the relatively much higher use made of enabling resources in comparison with operating resources. Since useful economic analysis matches the level of detail used to the proportionate size of the contributing resource considered, it is worthwhile here to develop more detailed economic relationships for considering the enabling resources component of CAI.

Analysis of CAI Equipment Cost

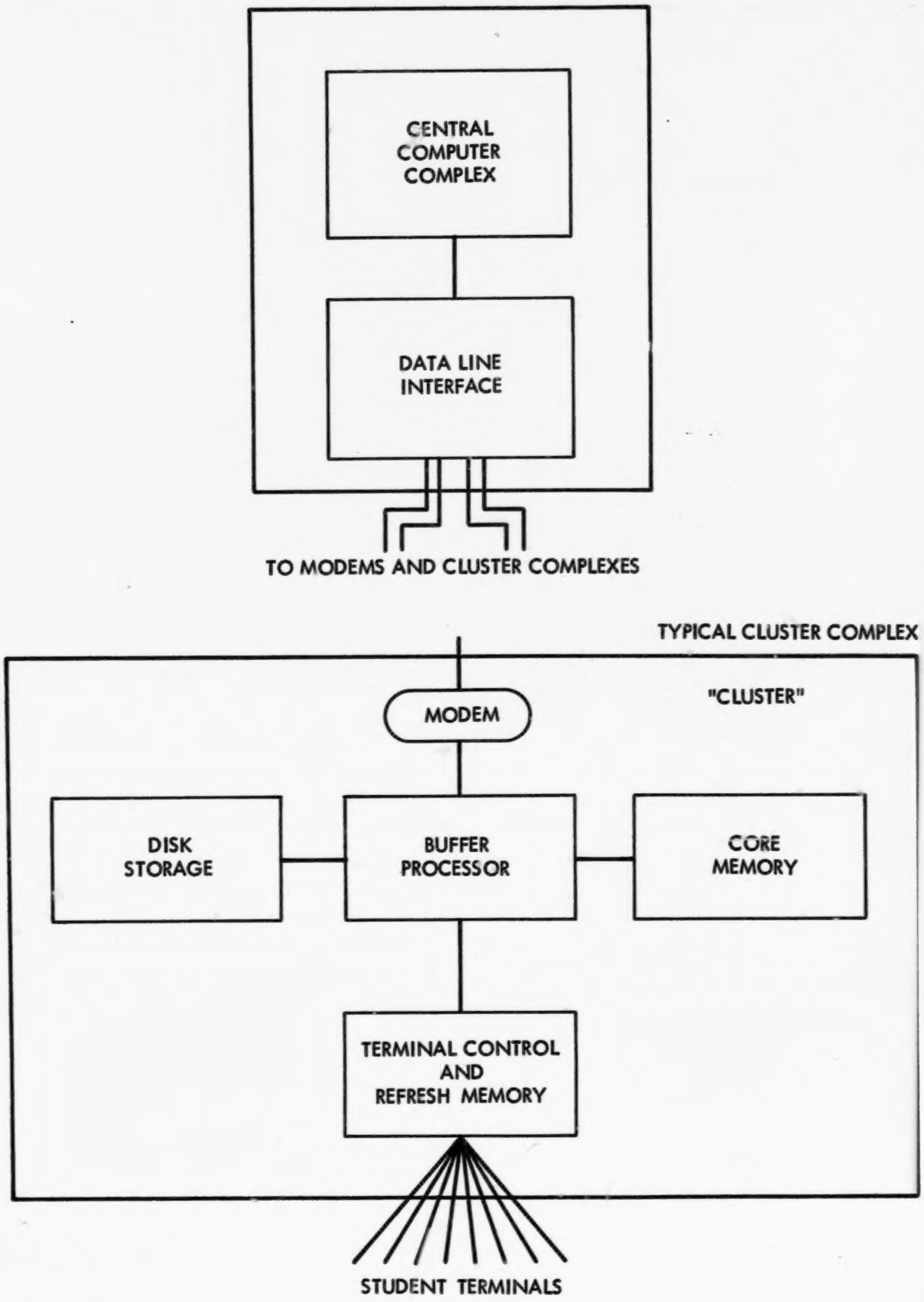
For purposes of gross economic evaluation, as was done under the examples above, the enabling resource component of CAI need be specified only in terms of "facilities requirements per student." Since this is generally a very high factor for CAI, however, a closer look at its constituent elements is warranted.

A note of caution must be interjected before further analysis is presented. The data processing equipment utilized by CAI is technically very complex. Specific items of equipment which go by the same or similar names may actually perform very different functions and their costs may respond in very different ways to changes in such factors as student usage. It is as much the interlocking set of computer programs which control these devices as the devices themselves which determine the size and nature of enabling resource requirements for CAI. This being the case, development of economic relationships based on the descriptive titles of items of CAI equipment (hardware) would be very hazardous. Such a line of attack would not only be susceptible to fundamental errors in characterizing the economic relationships involved, but also would not be sufficiently general to stand up for very long under the rapid rate of technological change occurring in the data processing field.

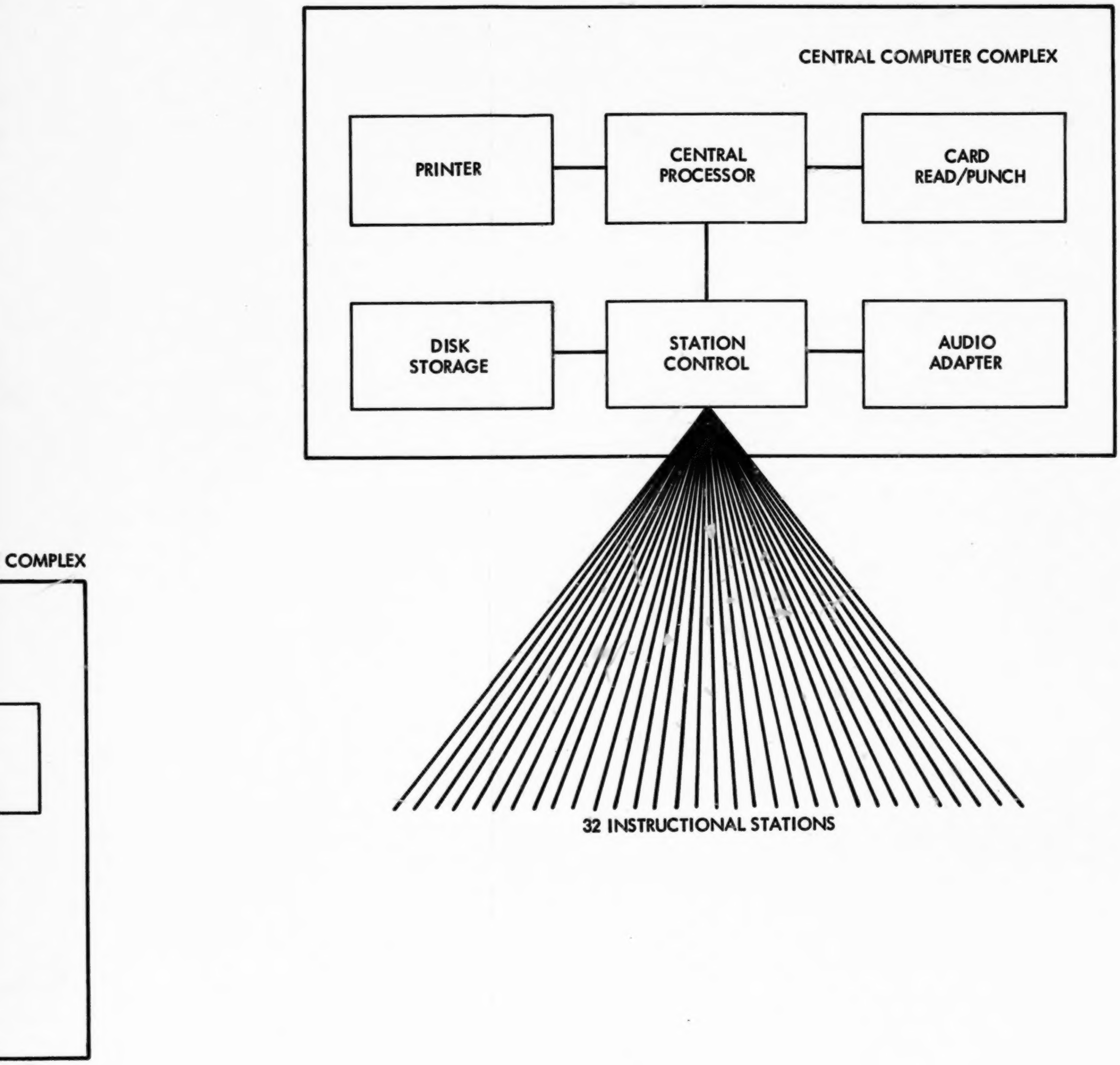
Figure 19 illustrates the importance of recognizing the need for caution in this area. Systems diagrams for two different CAI equipment configurations are depicted. Both are designed to carry on basically the same type of "learning communication" with students using them, but there are notable differences in the pattern of arrangement and types of equipment employed. Since a general cost model should be applicable to both of these systems (and indeed to other systems not yet dreamed of), it would not be feasible to base the model upon either one of the equipment configurations.

One solution to this problem is to resort to simplicity with the consequent avoidance of tricky detail. Such a solution would be represented by the approach which holds that no further breakdown of the "facilities required per student" factor be made.

Any more enlightening solution must come enmeshed in technical detail. Suggested here is an approach which is patterned after that taken for the COST-ED model as a whole -- the definition of cost factors on the basis of functions performed. This type of approach allows consideration of more detailed economic relationships than the "simplicity" approach, but conveniently avoids dependence upon specific configurations of hardware.


CENTRAL COMPUTER COMPLEX
DATA LINE INTERFACE
TO MODEMS AND CLUSTER COMPLEXES
TYPICAL CLUSTER COMPLEX
"CLUSTER"
MODEM
DISK STORAGE
BUFFER PROCESSOR
CORE MEMORY
TERMINAL CONTROL AND REFRESH MEMORY
STUDENT TERMINALS

PHILCO-FORD "GROW" SYSTEM –


CENTRAL COMPUTER COMPLEX
PRINTER
CENTRAL PROCESSOR
CARD READ/PUNCH
DISK STORAGE
STATION CONTROL
AUDIO ADAPTER
32 INSTRUCTIONAL STATIONS
COMPLEX

IBM 1500 INSTRUCTIONAL SYSTEM

Figure 19. Two CAI Equipment Configurations

A glance at Figure 19 shows that the following types of equipment modules are involved in a CAI system.

- Central Processing Units
- Data Storage Units
- Data Transmission Conversion Units
- Data Transmission Lines
- Data Transmission Buffers
- Branch Processing Units (auxiliary or remote)
- Display Support Units
- Man-Machine Communications Units (various types)
- Other Input-Output Units
- Student-Carrel Furnishings

It is here proposed that a more general and enduring basis for categorizing CAI facilities costs than the listing above is represented by the listing of functions performed.

- Instructional Process Control
- Curriculum Availability
- Student-System Communication

"Instructional Process Control" is the function performed by the logical, i.e., decision-making components of the system, such as the central and/or branch data processing units.

"Curriculum Availability" is the function performed by such system elements as magnetic disk data storage devices, visual cartridges, and communications lines.*

"Student System Communication" is the function performed by such display and input devices as cathode ray tubes, computer controlled and locally situated random access slide projectors, teletypewriters, light pens, and the like. Equipment items (or shares of the operating capability of more general equipment items) which immediately support these devices, e.g., special data buffers for refreshing cathode ray displays to avoid flickering, would also contribute to the student-system communication function.

The prime advantage of using this breakout of functions arises from the technically feasible trade-offs between items of equipment which support the same function. As examples:

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*While communications lines may actually be used in support of remote instructional process control equipment, they are included in this category on the assumption that their greatest use is for transmitting curriculum materials.

- A large central processing unit controlling 1,000 students stations may be economically and technically traded off against 10 smaller units, each supporting 100 stations, all within the Instructional Process Control function.

- Mass data storage at a central location plus communication lines to branch student terminal clusters may be traded off against duplicative data storage at each cluster with no central communications lines, all within the Curriculum Availability function.

- Cathode ray displays refreshed by a central processing unit may be traded off against displays with internal or cluster-shared refreshing devices and no dependence on a general data processing unit, all within the Student-System Communication function.

A second advantage of this breakout is that the economics of performing the first function are closely allied with the cost factor "cost per computer instruction executed", which is a generally available statistic, while the economics of the second function are similarly allied to two generally available cost factors, "cost per bit of data stored" and "cost per bit of data transmission capability."

A third advantage of this breakout is that cost-effectiveness relationships may be formulated using cost factors such as the above mentioned available statistics or the more complete factors of the form "cost per function per student-hour" for each of the three functions identified. As examples:

- It is possible to conceive of a relationship between instructional effectiveness and the complexity of instructional adaptivity decision-making performed by the CAI system. With the application of appropriate conversion factors, a relationship might be established between effectiveness obtainable and cost of computer instruction execution.

- Similarly, a relationship between effectiveness obtainable and size of curriculum variations available might be established using the factor "cost per bit of data stored and transmitted."

Unfortunately, there are not cost statistics for the student-system communication function available in formats comparable to those statistics mentioned for the other two functions. Perhaps this is not undesirable, however, as the need for separate economic treatment of each of the alternative media of student-system communication encourages recognition of the very different instructional characteristics of each.

Application of the tri-functional approach to costing CAI equipment requires, for each particular configuration of equipment employed, a procedure for distributing equipment costs among the three functions. A format which may be used for this purpose is illustrated in Figure 20.

Spaces are left on this format for including data concerning the actual usage planned (i.e., scheduled) for each of the equipment terms in the working configuration. This information on usage may be employed to develop percent utilization factors for use in calculating opportunity costs of unused facilities.

Application of this format to competing equipment proposals for the same instructional system will assist analysis of:

- The "growth" capability of the system;
- The "balance" in usage among different system components; and
- Cost-per-function comparisons among the alternatives.

Differences in cost-per-function as between competing systems may be traced to:

- Differences in system (e.g., computer program or configuration) design;
- Differences in the hardware capabilities of individual system components; or
- Differences in scheduled (or scheduable) usage made of the components.

This data may be useful in refining system design or usage plans for increased efficiency, growth capability, or the like. Such analysis may require a great deal of technical expertise, however. It is not possible to describe fully how it might be performed in this document.

A key characteristic of CAI equipment configurations is the sharing of central equipment by many pieces of end-user equipment. The Philco GROW System for Philadelphia, for instance, uses a central data processing facility to support local "clusters" of intermediate data processing units and each "cluster" to support many learner terminals (see Figure 19). In general, many levels of successively higher centralization may be used.

As a result, the number of identical units of each component of the system which appears in the total configuration depends on how far from the central control and how close to the user (the learner) the component appears. In the IBM 1500 System, for instance (see Figure 19), there are 32 sets of student terminal equipment for each central data processor. The Philco GROW system may have up to five cluster units, each with up to 50 student terminals, for a total of 250 terminals per system.

										COSTS BASED ON ANNUAL PLAN OF SYSTEM UTILIZATION							
					SCHEDULED SYSTEM UTILIZATION		DISTRIBUTION OF UNITS OF UTILIZATION PER STUDENT-HOUR			SCHEDULED UNITS OF UTILIZATION FOR TOTAL INSTRUCTIONAL SYSTEM				PRO-DUCTIVE COSTS	UNPRODUCTIVE COSTS		
ITEM OF EQUIPMENT	UNIT OF UTILIZATION	COST/UNIT OF UTILIZATION	CAPACITY: UNITS/YEAR	COST/YEAR	UNITS UTILIZATION/ ST-HR INSTRUCTION	OTHER REQUIREMENTS FIXED/YEAR	% INSTRUCTIONAL PROCESS CONTROL	% CURRICULUM AVAILABILITY	% STUDENT-SYSTEM COMMUNICATION	INSTRUCTIONAL PROCESS CONTROL	CURRICULUM AVAILABILITY	STUDENT-SYSTEM COMMUNICATION	OTHER USAGE	TOTAL PRODUCTIVE COST/YEAR	UNUSED UNITS OF UTILIZATION/YEAR	% UNUSED CAPACITY	OPPORTUNITY COST/YEAR
1.																	
2.																	
3.																	
4.																	
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.																	
N.																	
				TOTAL SYSTEM COST/ YEAR						PRODUCTIVE COST PER INSTRUCTIONAL FUNCTION PER YEAR				TOTAL PRODUCTIVE COST 1 YEAR			TOTAL OPPORUNITY COST 1 YEAR

Figure 20. A Functional Cost Analysis for Operating CAI Systems

Apportioning the costs of each system element to the individual user, we find for the Philco system as an example:

100.0% of cost of student terminal
2.0% of cost of cluster components
.4% of cost of central processing facility.

Furthermore, the economics of scale in data processing indicate that the more highly central and larger items are likely to have lower costs per unit of data processing ability.

The object of the preceding analysis is to emphasize that by far the largest component of cost per student-handling ability of the system is quite likely to be that of the student terminal equipment itself. Even for the not-very-highly centralized IBM 1500 system, the costs of a typical 32 station configuration are 76% for student terminals and 24% for centralized components. Given this characteristic of CAI equipment configurations, it is evident that cost-reduction efforts will pay the largest dividends if applied primarily to the student terminal equipment.

Similarly, the economics of expanding CAI installations from small-scale to larger-scale use indicates that the system with lower student-terminal costs will have an economic advantage. In light of the preceding section, however, this observation must be submitted to a technical analysis of the equipment and its operating programs before it is accepted at face value.

CAI Program Development Costs

Just as in any other example of automation, the development of computer-assisted instruction requires large investments of effort and capital. With CAI, moreover, this investment must be placed not only in research and development of equipment, but also in the research and development of CAI instructional programs, the format of the curriculum to be presented to learners by the CAI equipment.

The term "software" has been used to describe these curriculum materials. Unfortunately, this term has also been used to apply to the computer programs which process the original form in which curricular materials are presented into the computer-oriented form required for use. It has also been used to describe the language used by the student and the machine to communicate with each other. The ambiguity of this term will here be eliminated by definition of the following terminology:

- Machine Language - The basic language used to program the computer under consideration; the language in which all other (higher-level) languages for using the computer are written. (This is generally an "assembly" language.)

- Instructional Programming Language - The format used for curriculum subject matter and the specification of the manner in which this subject matter will be presented to the student. This is the language used by CAI program authors for developing CAI curriculum materials.

- CAI Curriculum Materials - Specific examples of subject matter to be taught (learned), written in an instructional programming language. The term "CAI Program" has been used, and will be used below, to refer to an individual example of curriculum material.

- Student/System Communication Language - The language in which the student may phrase his communicated input to the computer system. This is generally similar to the language in which the computer can construct original (i.e., not pre-stored)verbal messages for output to the student. The nature and complexity of the student/system communication language is generally reflected in the formats, rules, and procedures for the instructional programming language.

For purposes of further clarification, the terms "learning objectives" and "subject matter" will be used below to refer to what is to be taught.

With these terms defined, a discussion of factors which influence the costs of CAI program development can begin.

A functional division of costs incurred in the preparation of CAI curriculum materials might be made as follows:

- CAI curriculum materials authoring
- CAI curriculum materials validation
- Administrative overhead

Depending on the type of organization conducting the curriculum materials effort, such other functions as marketing and distribution of the materials could be added.

A type-of-resource division of costs incurred in the preparation of CAI curriculum materials might be made as follows:

- Personnel
    - CAI curriculum materials authoring
    - CAI curriculum materials validation
    - Administration
    - Computer operations

- Supplies and materials
- Computer time
- Use of proprietary software

In this cost category "software" is meant to include primarily the instructional programming language. Historically, up to 1967, there had not been explicit charges for instructional programming languages in use between organizations. Such charges may arise in the future, however, and provide a vehicle for amortization of intraorganizational effort to develop these languages.

It appears that the largest component of CAI curriculum materials development costs arises from the personnel effort in materials authoring. Current estimates of the effort required are in the range of 200 man hours required to convert one hour of classroom instruction to CAI format.

This figure must be taken as highly tentative. Furthermore, this statistic is very highly variable, depending on the situational context.

Factors which influence the amount of effort required to develop CAI curriculum materials include the following:

- Existing definition of learning objectives.
- Systematization of programming procedures.
- Experience of programming staff.
    - Instructional programming techniques.
    - Subject matter.
- Comprehensiveness of instructional programming language.
- Span of learning objectives.
- Dimensionality of student error possibilities.
- Calculability of automated response.
- Level of adaptation in CAI program.
- Refinement of style in CAI program.
- Learning set and aptitudes of learners.

Each of these factors is discussed in turn below.

The definition of learning objectives is the task of preparing a detailed and explicit statement of what is to be taught and to what levels of proficiency the learners are to be able to perform. ("Terminal performance objectives" is another name used to describe the same statement.) The statement of learning objectives is generally the product of task analysis and involves fleshing out high-level behavioral objectives into component skills and items of knowledge.

Defining learning objectives for the first time in any instructional setting is a long and difficult job because the result must be complete in every detail. To the extent that learning objectives are already well specified in advance of CAI program development, the program development effort can proceed directly without this first time-consuming step.

Systematization of programming procedures for CAI course development refers to the orderliness with which the programming effort can be carried out. The procedures involved include both those related to the technical aspects of authoring techniques and the administrative aspects of managing the programming effort.

Current CAI program development is generally carried out on a cut and try basis. Patterns of adaptation to the differences among individual learners have so far remained quite unsophisticated. The reason has been the lack of an accepted and comprehensive model of the instruction/learning process which provides clear guidelines as to how a given set of learning objectives should be converted to a CAI instructional program.

The lack of comparability between experimental results of using CAI and the inability to reproduce results across different CAI course material programs are the results of desparate and unsystematic guidelines and procedures for CAI course development. Wasted efforts and difficulties of coordination and management within groups working on the same CAI program also result from the lack of systematic procedures. These latter results increase the net effort required to produce CAI curriculum materials. The extent of this increase is directly proportionate to the level of sophistication attempted in the CAI program.

Systematization of programming procedures — which should be a result of applied research in building a model of the instruction/learning process — would reduce costs arising from these sources.

The experience of the programming staff is a factor which speaks for itself and needs no elaboration here. To a large extent, this experience is reflected in increased systematization of programming procedures.

The comprehensiveness of the instructional programming language may be one of the largest determinants of the effort required to produce CAI curriculum materials. If the curriculum development effort is divided into two stages — curriculum substance design and translation into the instructional programming language — it is seen immediately that the nature of that language itself strongly determines effort and cost requirements in the second stage. A subtler, but perhaps more important, effect of the programming language used is its influence on the type of person required for the developmental effort. To the extent that the language is a highly technical or esoteric one, a specially trained and more expensive staff may be required for CAI program authoring.

The most important effect, however, arises from the extent to which the language is able to assume into itself and automate low-level functions which might otherwise be required of curriculum materials authors. For instance, if the language has automatic features for recognizing and handling student responses which are simply spelling or typographical variants of the correct answer specified, author effort which would be spent in providing for all these variants of student response may be saved. Similarly, features of the instructional programming language which allow the design of cathode ray tube displays by programmed refinement of rough sketches made with a light pen or on a Rand tablet, instead of requiring specification of Cartesian coordinates of all points to be displayed, can save large amounts of programmer effort.

The "comprehensiveness" of the instructional programming language is meant to indicate the extent to which functions such as these are automated and removed from requirements on course authors. It is easy to see how strong an influence on total author effort required these factors may have.

The span of learning objectives refer to one of the measures of subject matter complexity. The term "span" is meant to refer to a qualitative measure of the size of the steps to be taken by the learner in achieving the learning objectives. It may, for instance, require more effort to teach a young child the concept of "number" than to teach a college student the basics of relativity theory, though common usage would term the latter the more "complex" subject matter. While objective measurements of the span of specific learning objectives chosen for a CAI program may not as yet be feasible, a qualitative appreciation for this dimension may be of assistance in estimating effort required for CAI program development.

The dimensionality of student error possibilities refers to the number of distinct wrong responses of the learner to a machine-posed question which must be provided for in an instructional program. Development of an instructional program which utilizes only true-false choices as the student/system communication language, for example, will generally require less effort than one which uses multiple choices. This will require less authoring effort than one which uses student-constructed responses, and so on.

The calculability of automated response refers to whether distinct student responses must be separately provided for in the CAI program or whether one algorithm in the program may be applied to them all. Typically, for instance, student responses which are verbal in nature must be provided for separately; those which are numerical in nature, however, may be handled with only one programmed procedure capable of reacting to an infinity of different student responses. Similarly, simulation of electric circuits, industrial processes, equipment operation, and the like on a computer may be designed to allow all kinds of student manipulation of the subject being simulated without the need for separate treatment of all possible student actions.

To the extent then that a single programmed algorithm can handle many different (and/or sequential) student responses, CAI curriculum development costs may fall. Note, however, that there is a breakeven point such that the costs of developing an extensive algorithm for handling student responses are justified only if that algorithm receives sufficiently frequent usage in the instructional program.

The level of adaptation in the CAI program describes the sophistication of the programming procedures used to individualize presentation of the subject matter to the needs of different learners. One measure of the level of adaptation in a CAI program is the dimensionality of student error possibilities (described above) provided for. Adaptive sophistication of a CAI program, however, involves much more than this. For instance, a program which branches the presentation on trends in student performance measures may be taken as more sophisticated than one which branches only on the correctness of the student's last response, and can be expected to absorb more effort in its authoring.

The refinement of style in the CAI program refers to the care with which the program is edited for style, humor, motivational qualities, choice of language, and the like.

The learning set and aptitudes of the learners for whom the program is being written may have a large influence, directly or indirectly, upon requirements for program development effort. Low aptitudes, for instance, may increase the span of the learning objectives (see above). Low prior motivation may increase the need for refinements in style (see above). In general, this factor recognizes that it is less difficult to write an acceptable CAI program for mature, well motivated, high aptitude learners than for other types.

It might best be noted here, also, that the variability within the audience of learners along such dimensions as aptitude and motivation creates a need for a higher level of adaptation in the CAI program and thereby increases the effort required for its development.

A summary comment on the factors influencing CAI program development costs would tie many of those isolated above together. The effort required will depend most directly on the quality demanded in the final product.

Charge of Developmental Costs

The costs of developing CAI curriculum materials may amount to a significant fraction of the total capital investment needed to begin a CAI system. But there are numerous problems encountered in finding ways to charge these costs against the students who benefit from them in such a fashion as to facilitate comparative economic evaluation of CAI with other instructional techniques.

These problems arise from several directions. First, no market has arisen which uses any particular technique for pricing the services performed by CAI curriculum materials. Actually, there are some similarities between the economics of textbook authoring and those of CAI program authoring. Textbooks are sold at a fixed unit price, however, but thus far there have been no "sales" made of the unit equivalent of usage of a CAI program. The problems of copyrighting CAI curriculum material also contribute to this situation.

Also of relevance, however, is the practice of continuous adaptation and revision of a CAI program by its users — a practice not found in the textbook example and one which ultimately destroys the identity of the original version of the program. This practice also leads us to the second major type of problem in development costs. This is the difficulty of finding an appropriate basis for amortization of the developmental (capital) outlay involved in program preparation. The costs of a building may be prorated over its expected lifetime, i.e., the time until its replacement or abandonment is expected. A CAI program, however, may indeed never be replaced or abandoned; it may just continue to undergo revision and improvement. This point may be underlined by reference to the problem of finding a way to depreciate the expenses incurred by Euclid in writing his Elements!

Without a market established pricing mechanism or a logical basis for amortization, charging CAI program development costs must be done in an arbitrary fashion. Two methods of treating CAI program development costs are considered below.

- The first method is not to charge for these costs at all, but rather to consider them as nondepreciable "transition" costs. This approach recognizes that the only reason for compulsively seeking a basis for amortizing these costs is to help decision makers compare CAI methods to alternative instructional techniques. It suggests that cash flow and present value analysis be substituted for expense accounting in comparing the economics (or cost-effectiveness) of alternate instructional methods. With this approach, CAI program development costs would represent an initial cash outlay, hopefully justified by increased effectiveness and/or decreases in future operating expenses (which would include those for CAI program revision).

- The second method is to amortize CAI program development costs over all students using the program within a specific time period. This time period might be arbitrarily chosen as:

  - Twice the half-life of unrevised sections of the original CAI program; or,
  - The debt retirement period for funds borrowed to support such capital outlays as facilities construction and CAI program development.

No one of the alternatives for treating CAI program development costs is here recommended as generally superior to any other. Each may be most appropriate in certain situations and least appropriate in others. The discussion above has served simply to identify the problems involved and note alternatives available.

One further point should be commented upon, however. Regardless of what amortization period or method of charging is employed, the wider a CAI program is used the easier is the economic justification for its development expenses. This factor will act as a source of pressure for curriculum standardization.

The All-or-Nothing Effect

No words need be expended to describe how fundamentally different CAI is from traditional methods of instruction. The large differences between the economics of CAI and those of classroom instruction were outlined earlier.

It is for these reasons that CAI cannot be economically justified as an additive to the classroom pattern; it can only be justified if it becomes the dominant pattern of instruction in any given instructional environment. This means that the organizational and administrative patterns of the instructional situation must change to recognize the individualization which CAI brings to the instructional process.

The example of trade-off analysis using the COST-ED model given above showed an economic justification of the higher instructional costs per student-hour which CAI may initially be expected to have was strongly dependent upon savings in learning time. Obviously, if CAI is just used for a few minutes a day in the ordinary classroom and grade-level pattern of education, it will not be permitted to show reductions in time required for graduation, and will not easily be economically justified. (Note, however, that if time savings are not allowed, the increase in average learning rate assumed for CAI may lead to an enrichment or extension of average learning in terms of depth or quantity.) Individualized scheduling of students is also a necessary prerequisite to the economic justification of CAI.

The sensitivity of instructional costs to facilities utilization peak factors similarly shows that maximum utilization of the enabling resources demanded by CAI is also essential to its economic justification. Again, the capital costs of CAI equipment will not be justified by only a few minutes' or hours' use a day. Procedures for maximizing the around-the-clock, around-the-year use of CAI equipment are critical to its justification, and such procedures may dictate a basic change in the concept of the school day or the single-purpose use of school facilities.

It would be economic folly to allow CAI to be misused in the same way that instructional television and programmed instruction have been misused — the first, by not reducing classroom instructor costs when the television is in use; the second, by fitting programmed instruction booklet use into fixed-length class period.

With CAI, the economics more forcefully cry for all-or-nothing application.

Summary

The construction and exercising of the COST-ED model has highlighted the most important relationships in the economics of instruction. This section provides a capsule summary of the most central economic considerations which must be understood before any basis for the efficient management of instructional activities can be laid.

Key Factors in the Economic Analysis of Instruction

Any precise economic analysis of an activity as complex and varied as instruction cannot avoid due attention to large numbers of details. From these, the following considerations and cost factors are noted as the most important for the comparison of alternative instructional techniques and methods.

- Time to Learn.
  As shown in the New York and military examples, this factor is generally the single most important determinant of total instructional costs. These costs are usually more sensitive to changes in this factor than to changes in any other.

- The Overhead Factor.
  The overhead factor is the ratio of total time-dependent costs to the one particular time dependent cost under consideration.

  It is a key determinant of how much the factor considered changes when traded off against changes in time to learn within fixed total cost per unit of student achievement.

  Figure 21 shows the relationship between savings in time to learn, justified percentage increase in instructional costs per unit time, and the overhead factor.

  Note that situations in which the learner is paid or in any other way receives the benefit of high student support costs are the ones where time savings justify the greatest increase in costs of the instruction function itself or any component of it.

- Use of Teacher Time.
  In most current instructional situations, the largest single component of instruction function costs is the compensation of teachers and related expenses.

  Although the costs of all paid-for teacher time must be charged to students only during that time in which they are receiving the benefit of the teacher's instruction, not all of the teachers paid-for time is spent in student instruction. In many cases, forced complementary

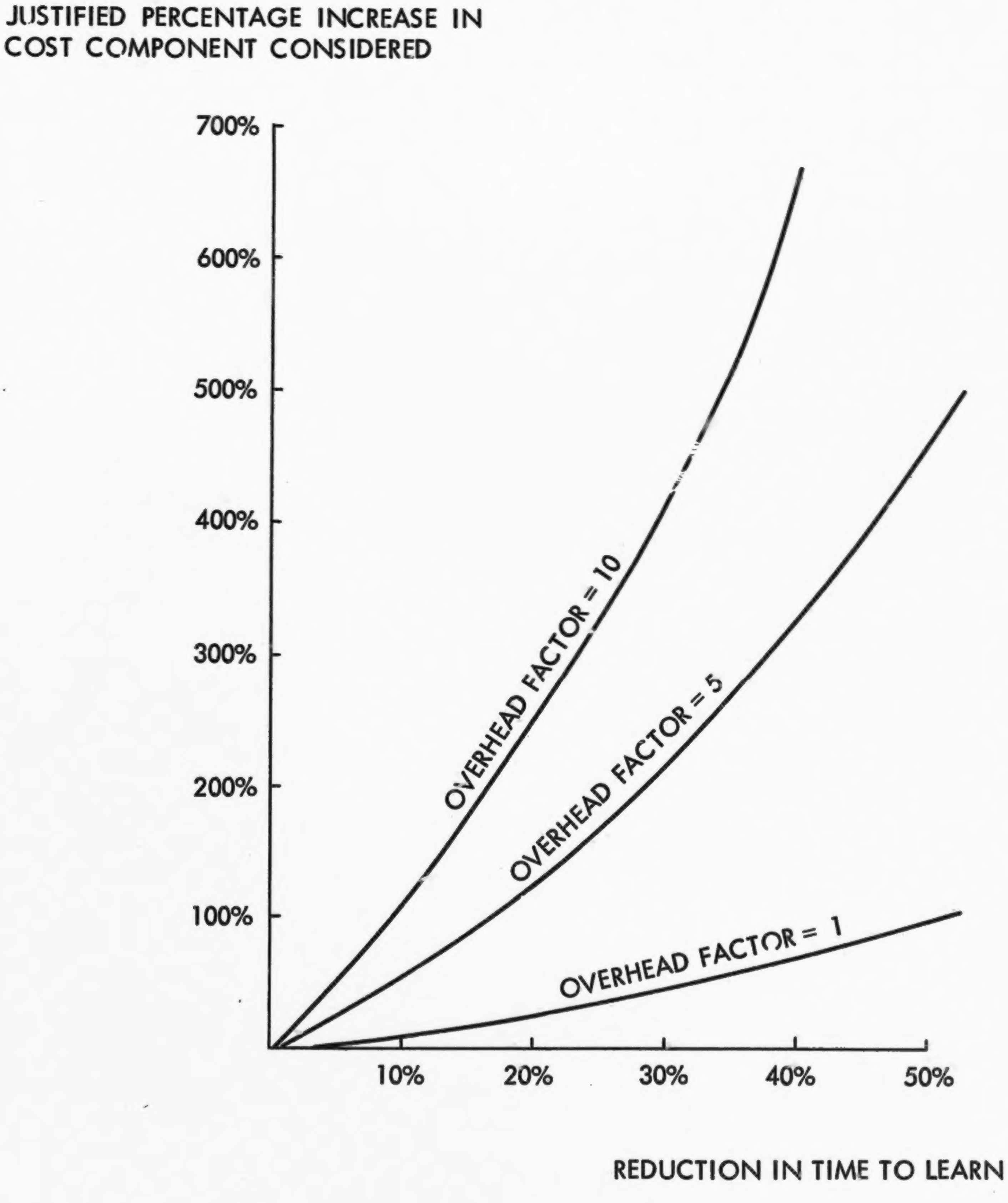

Figure 21. Effect of the Overhead Factor

activities remove the teacher from the direct instruction function itself for a large percentage of his time.

It is easy to see that any organizational, administrative, or technical device which reduces the need for the teacher to engage in paid-for forced complementary activities will increase the proportion of his time effectively spent teaching. As his teaching hours increase, so does the basis for distributing his total paid-for time costs with the result that costs per unit of teacher time spent in active instruction fall.

This relationship was not illustrated in the foregoing examples, but is provided for in the COST-ED model. For example, increasing the percent of the teacher's work week spent in active instruction from 66% (current national average for secondary school teachers) to 80% would cut teacher costs by about 16% per student hour and have the same economic impact of a reduction in total teacher costs per year by that amount.

- Free Resources.
  Time contributed by teachers after hours is a free resource in that performance of the same functions during the school day would increase total costs and could not be justified by any economic gain arising from saving of teachers' after-hour time.

  Although not shown in the examples provided above, one of the teacher's uses of his after-hours time is the preparation of lesson materials. If this function is to be paid for and performed (as contemplated for CAI) by experts during the working day, the cost of this work will not be justified by savings in teachers after-hours time, and will represent a net increase in total costs.

- Student : Teacher Ratio.
  Just as in the case of the use made of teacher time, the student : teacher ratio is a key parameter determining how total teacher costs are allocated to student-hours of instruction.

In the case of the New York City high school, where the student : teacher ratio was high to begin with, a given percent increase in this factor was less productive of justification for increased instructional facilities investment than a similar percentage decrease in total teacher costs. In cases such as the military, however, where the student : teacher ratio is much lower (due in part to higher requirements for forced complementary activities for the teachers), increases in this factor may be more productive than similar percentage decreases in teacher costs.

- Facilities Utilization Peak Factors.
  Figure 13A showed vividly how sensitive facilities utilization costs are to their corresponding peak factors.

  To the extent that facilities costs comprise a large portion of total instructional costs, the importance of reducing the peak factors through fuller scheduling of facilities utilization is increased.

  This will be one of the most important considerations for CAI.

Areas of CAI Comparative Advantage

The preceding section listed the key economic considerations pertinent to the comparison of alternative instructional methods. In combination with the factors noted in the discussion of cost considerations for CAI, these factors point to the following as characteristics of those instructional environments in which CAI is comparatively most economical.

- Possibility of Savings in Time to Learn.
  - Situations in which large groups of learners are forced to progress at the pace of the slowest among them, and in which there is sufficient spread in learning aptitudes so that the faster students would learn much more rapidly than the slower ones.
  - Situations in which the computer can effectively (through simulation or otherwise) speed up the learner's physical learning activities.
    - Computer simulation of such processes as slow reactions in a chemistry laboratory

    or the operation of a piece of heavy equipment (e.g., an airplane or a tank gun firing mechanism) is one example of how this type of situation may be encountered.

    - Use of the data processing capabilities of the computer in the learning process itself (e.g., for architectural students learning to design a bridge) is another example of how this type of situation may be encountered.

  - Situations in which the inevitable rigidities of scheduling blocks of students in classes lead to inefficient usage of student time. (In the military, for instance, service schools generally carry a load of students who are either waiting for their scheduled course and class to begin or waiting to mesh with another schedule at the completion of their training.)

- High Overhead Factor for Instructional Costs.
  As noted in the preceding section, situations in which student support costs are comparatively high are those for which savings in time to learn free up the most resources for investment in such facilities as CAI equipment.

- Ability to Schedule Full Use of CAI Facilities.
  The fuller the use made of the student-hour capacity of CAI facilities, the lower the facilities peak factor and alternately the costs per student. Situations in which around-the-clock usage of CAI facilities can be approached will more economically justify the investment in CAI facilities than situations where other considerations limit use of the CAI facilities to a small part of their around-the-clock capacity.

- Computation-oriented Subject Matter.
  Cases where student-system communication and the development of CAI curriculum materials permit computation of system responses to student actions or decision are more likely candidates for CAI than cases where the development of curriculum materials must provide separately for a wide variety of student actions.

- Large Audience for Curriculum Materials.
  As pointed our under "Cost Considerations for CAI", the larger the number of learners to be exposed to a CAI program, the easier it will be to justify the costs of developing it.

- High Training time : Productive-time Ratio.
  As shown in the military training example, cases of training in support of fixed manpower requirements in which training time and productive service time share the same period of manpower availability can justify a higher investment in CAI facilities per unit of training time saved than situations facing fixed requirements for student throughput. This was the factor highlighted in Figure 18.

- Possibility of Reducing Forced Complementary Activities.
  Situations in which CAI may reduce teachers' forced complementary activities and increase the percentage of their time spent in active instruction will more readily produce savings to justify expenditures for CAI facilities than situations where CAI will have a lesser effect on the utilization of teacher time.

- Possibility of Increasing Low Student : Teacher Ratio.
  Significant increase of a low student : teacher ratio in situations where teacher costs represent a large component of total instructional costs will provide a large source of funds to justify CAI investment.

The situational characteristics noted above do not necessarily describe those cases where CAI may be more economical than other instructional media today. Rather, they describe those situations where CAI is more economical than in other situations and those situations where CAI is most competitive with other instructional techniques.

Note that only economic considerations have been dealt with here. No attempt is made to consider learning effectiveness in describing situations of comparative CAI advantage. Considerations of effectiveness might lead to many other types of situations in which CAI has a comparative advantage over other instructional techniques.

Conclusions from Economic Analysis

Economics exerts strong pressures upon the manner in which productive resources are employed. But economics is not the sole source of pressure which shapes such matters. Particularly in the field of education and training, social and cultural pressures may well contribute as heavily as economic pressures to the shaping of the future.

To the extent that economic pressures will themselves have an influence on the future use of CAI, however, the following conditions may be drawn.

- The first applications of CAI will be in the military and welfare sectors of the nations, followed shortly in the industrial sector. Use of CAI in public general educational institutions will be minimal until costs of CAI facilities fall sharply.

  This conclusion is based on consideration of the overhead factor, the training-time: productive-time ratio, size of audience, facility scheduling flexibility, and student and national opportunity cost factors.

- Large CAI facilities will be used for far more time than the normal working week, even if different types of users and educational programs are involved in sharing the same facilities.

  This conclusion is based on consideration of the peak facilities utilization factor.

- CAI curriculum materials will be prepared for mass distribution and usage, but provision for local adaptation and "user-group" information exchanges will be made.

  This conclusion is based on consideration of the size of the audience in the context of local school district autonomy and industrial user competition.

- Widespread application of CAI must be preceded by the development of a very comprehensive instructional programming language suitable for use by minimally-trained persons.

  This conclusion is based on the recognition of the importance of the comprehensiveness of instructional programming languages in reducing CAI course authoring costs, in the context of political and organizational demands for local control of curriculum materials.

- CAI will not be used where administrative and organizational changes cannot be made to permit adoption of individualized scheduling of learning as the norm.

  This conclusion rests on the importance of saving learning time and levelling peak facilities utilization through scheduling techniques for justifying the additional costs of CAI.

This last conclusion is perhaps the key one. As brought out under "The All-or-Nothing Effect", the economics of CAI will not allow its use in other than individualized learning situations, except for very limited special cases. The management of educational enterprises will have to make the needed administrative and organizational changes in the conduct of the instructional process before economic justification of CAI approaches reality.

GUIDELINES FOR CAI

Significance of Guidelines for CAI

CAI is a novel and unique instructional medium offering unknown potential, but the cost of research and development to realize this potential is inordinately high. Therefore, it is imperative that well selected development occur so that a decision regarding direction and level of funding effort in promising areas can be determined as soon as possible.

A particular problem arises when guidelines are developed for CAI related activities. Conceptually, one can separate computers used to instruct from computers used to do research on instruction. CAI offers this latter potential to a degree which other media do not. If guidelines take into account these two functions and the benefits from both are presented separately, evaluation of cost effectiveness can be more accurate and realistic.

Last, but most significant, guidelines regarding CAI can improve communications between sponsor, contractor, and user. Potential contractors need to know the procedures and criteria for evaluation of their proposals and projects. This is particularly true in CAI development because of the scarcity of skilled manpower, the difficulty industry has in holding teams together during discussions and contract negotiations, and the internal management planning problems involved in obtaining and maintaining high level company interest in a new field such as CAI. Sponsors' communications with the users are important, because users, such as public schools, often define their problems differently from the project sponsor, e.g., the U. S. Office of Education. In addition, guidelines may help potential users to become aware of the intricacies and complexities of using CAI. Guidelines also communicate priority and relative emphasis among the Federal agencies that fund projects related to CAI.

Existing Major Problems

Partly because of the lack of effective guidelines and partly because CAI is a recent entry on the industrial and educational scene, the following problems are large and should be considered for intensive study and analysis.

First, public policy relating to CAI has provided inadequate direction to ensure its timely development and testing. A statement of priorities based on existing gaps in CAI research and development; efforts in this area by agencies other than the U. S. Office of Education; and activities financed by private or university sources needs to be articulated. The problem is not so much the lack of a sense of priorities as much as it is a failure to communicate these priorities to politically responsible officials for organization into an overall plan and strategy.

The absence of a consistent policy for the assignment of financial support to CAI projects has resulted in duplication and confusion within and among the agencies concerned. A few examples will suffice.

- It was recently reported that at least 60 projects relating directly or indirectly to CAI are on-going in only one branch of the Defense Department.
- Managers in industry who seek internal research and development funding for CAI based on priority statements made by responsible public officials have encountered frequent contradictions in these statements.
- Contractors are submitting reports and feasibility studies to more than one sponsoring agency.
- Potential large-scale users are unaware of possible applications or, if aware, are informed so late in the stages of development that there is little possibility for their participation and, therefore, acceptance is less likely.

Secondly, CAI has not been made legitimate. Industry has not accepted the role of making it a legitimate method of instruction. Certain CAI instructional systems can be used operationally in certain types of instruction; yet, public utterances by company representatives maintain that it is still experimental. Results of in-house use of CAI have not been published widely.

In the DOD, the largest sponsor of directly related research and development in CAI is the Advanced Research Projects Agency (ARPA); yet, its $30 million effort over the last three years has been funded as "information processing techniques" development and reported as such. Use of CAI in the military has occurred at security schools (e.g., Army Security School at Ft. Devens, RADC) because of the ease of hiding costs of development in public hearings for "security reasons." Some formal military training schools use CAI but usually the projects are funded under large funding categories like Operations, Maintenance, and Administration; and, therefore, are not reported through the Defense Documentation Center. CAI is being used in training subsystems (e.g., NIKE X, proposed AVIS system) where developmental costs can be hidden through tiers of subcontracts or shared jointly with hardware costs. The use of CAI in the CIA, poverty programs, or in military test beds (e.g., the Naval Academy project supported by USOE) all indicate that few officials are willing to make research and development in CAI legitimate to those who provide funds, in areas other than sheer rote and drill. While such passivism might be politically wise, it certainly tends to hinder accurate reporting for both internal management of research and development and for effective communication between the potential users across the public education spectrum.

Third, existing CAI projects have not reached "critical mass" levels. Large projects such as PLATO I-IV, Project MAC, Brentwood, and two or three others have produced well over half of all the scholarly literature which has contributed to advance the state of CAI development. A random sampling of 38 DOD-sponsored projects related directly or indirectly to CAI development in 1966 indicated that the average project size is about $28, 000 with over 85 per cent less than $200, 000. Moreover, about 50 per cent of the dollars are spent at 35 per cent of the geographic locations. Since 1965, the U. S. Office of Education has funded about 110 research and development projects relating to CAI; yet, the average size is approximately $125, 000 with only two greater than one million dollars per year. Certainly political pressures can be allayed much easier when projects are spread over larger numbers of political jurisdictions. Yet, if the quality of the research is desired to determine the relative effectiveness of CAI, it is essential that the size of individual projects be increased and directed as such.

Fourth, the premature attempts to apply cost effectiveness analyses to CAI not only have distorted reporting but also have been misdirected. A typical effectiveness criterion is to compare CAI per hour of instruction to a master tutor; yet, little attempt is made to determine what a tutor does functionally and why what he or she does is effective. The obvious difficulty is the lack of criteria for measuring effectiveness. It is interesting to note that the Department of Defense funded the first CAI project in the mid-fifties. Over time the difficulty of measuring effectiveness of CAI became so apparent that under Project THEMAS (funded in FY 68) it was decided that DOD would fund only those CAI projects purporting to develop standards for measuring effectiveness of CAI. Until criteria based on learning performance standards are developed, there will be little gained by attempting to apply something more than "common sense refined" (to the extent that hard data exist) much less cost effectiveness analysis of CAI versus other techniques. While cost models like that presented in Section I provide methodologies for analyzing cost, only half of the problem is solved.

Fifth, the demonstration clauses which have been written into most of the Great Society legislation concerned with applying new technological solutions to old problems will probably be recorded by political historians as one of the most significant political innovations of the sixties. Yet, administrators will readily concede that such demonstration clauses have not been used effectively, partially due to political reasons and to the tendency to fund under demonstration clauses what could not be funded under other titles because of legislative restrictions (e.g., contracting with profit-making firms). However, a major explanation lies in the confusion between demonstration "value" and demonstration "effect" and the development of procedures to deal with each separately.

The demonstration value is essentially how well the particular technique or approach being tested did work, i.e., what level of performance was achieved under what conditions. The demonstration effect, on the other hand, is concerned with the diffusion of the technique (if it was proven effective) to all other applicable situations. As students of innovation have often noted, the "bandwagon effect" is becoming an increasingly essential element in diffusion of innovations as our society grows more affluent, as some bureaucracies administering public service programs become increasingly internalized. Many industrialists are basing their marketing strategies on person-to-person communications between teachers and principals, hoping they will create this effect. Since criteria for measuring learning achievement are sparse, school administrators have a convenient rationale for rejecting many effective innovations but accepting others for the wrong reasons. Procedures could be developed and utilized to implement rational support for improving the demonstration effect in CAI. These procedures discussed in the public policy section of the report, are integrated into the suggested guidelines.

Sixth, the lack of skilled manpower in areas related to CAI is well known. Cognizance of this fact, however, should affect the approaches taken by sponsors of research and development activities. The problem is twofold -- the lack of quality research personnel and inadequate capabilities in program management.

In 1963 there were about 1,500 researchers who contributed to the solution of education problems. In 1966, this number jumped to 6,000. It has been estimated that universities produce only about 250 researchers annually. Like the growth of "scientists" and "engineers" in the defense research and development buildup during the 1950's, the increase in dollars through the legislation enticed many less qualified individuals into the field.

The lack of quality research and development in education, including CAI, points out the greater need for better program management if results are to be achieved. Good program managers have not developed in this field for several reasons. In the university the researcher rather than the manager has high peer acceptance. Only recently have many non-defense agencies begun to use the contract system rather than the grading system with universities; hence, the need for universities to develop indigenous program managers has only recently arisen. For the same reason, at the Federal level, the need for qualified research and development managers is new. Since the U. S. Office of Education only recently began contracting with industry and universities for research and development activities in CAI, it is imperative that this "program manager" problem receive high priority. When the National Institutes of Health recently began to use contracting rather than granting procedures, the highest priority recommendation by the Task Force which studied the transition was to develop a cadre of capable program managers. The Department of Defense, the largest Federal agency contractor for "personnel research and development" has a ratio of one manager-administrator to five investigators. A similar ratio needs to be developed in those agencies which support research and development in CAI related areas.

Last, the failure to develop guidelines which concern not only support for pilot programs using CAI but also their expansion (given the realities of our existing education system) has perpetuated a significant oversight -- namely, the need to develop flexible management systems to realize the time and other cost savings projected in pilot programs through the use of individualized CAI modes of instruction. The need for better instructional management systems is requisite for any wide scale effective usage of individualized instruction (e.g., over 90 per cent of all programmed texts used in the military are used as additives and supplements rather than being integrated into the formal school curricula because of this very reason). The opportunity offered by CAI is that it provides a simultaneous management capability. And in doing so, computer-managed instruction is providing the framework through which CAI will enter the classroom in other than pilot and experimental programs. CAI guidelines and high level public policy must be cognizant of this fact and proposal evaluators should not only be concerned with the administrative costs required to realize savings shown through proven CAI courses but, in funding CAI projects, should also insist on the development of a data base on the administrative changes required and the costs thereof.

While the problems above are not unique to CAI development, concerted efforts to move toward solutions in the field of CAI might demonstrate the need for closer overall scrutiny in non-defense public service research and development areas because of the costs and potentials involved in CAI. Below is a suggested approach to developing guidelines for soliciting and evaluating CAI proposals. The guidelines are not meant to replace existing U. S. Office of Education administrative guidelines but rather to provide a framework for rational decision making in an area of educational research that has unusually significant implications.

Suggested Guidelines for Submitting, Soliciting, and Evaluating Projects Concerning CAI

Computer-assisted instruction is the most sophisticated medium of educational technology offering great potential for improving learning. Educational technology deals with the process of learning. The learning process, in turn, is measured by the time and costs it takes a student to proceed from one level of performance to a given higher one. Educational technology assists in measuring the success of this process. In both operational and research and development stages CAI assists in achieving this goal.

A fundamental goal of the Office of Education is the increase in the use of efficient cost-reducing innovations in public schools in the United States. To achieve this major goal USEO has three objectives, all equally important.

- To support, either directly or with other Federal agencies, the research and development of those CAI projects which will increase student performance in existing and/or new public education programs (e.g., elementary, secondary, adult literacy, etc.)

- To promote the rate of adoption of those CAI systems which have been proven or validated by demonstrating them to the greatest number of potential users; and

- To support those CAI developments which offer the greatest potential for low cost replication.

Purpose

The purpose of these guidelines is to supplement the official USOE guidelines for the Bureau of Research, etc., by:

- Describing the kinds of projects using CAI which might contribute to the improvement of education and, therefore, be eligible for funding under Titles I, III, IV, etc;

- Giving an idea of the questions which need to be answered in the proposal once the decision has been made to submit a proposal which purports to evaluate or use CAI; and

- Providing a rational framework in which proposals to solve similar problems can be judged in light of alternative proposals which have been submitted or could be solicited.

In order to develop a taxonomy on CAI programs for rational decision making internal to the USOE to be used for determining support for solicited or unsolicited proposals, it is critical that the proposal specify the problems being attacked, the results which might be anticipated, and the time phases when these results can be expected .

Definitions

Technology might be defined as the art of applying. In the development of technology such as CAI, there are usually three phases.

- Applied Research: that research the results from which provide an input which will eventually improve the levels of program performance in achieving a certain goal. The objectives of applied research are among others:

    - To gather and organize existing data so that it can be analyzed in light of a specific goal;
    - To develop precise statements of the problems and sub-problems involved in achieving a goal;
    - To point out the relevant alternative means which provide solutions; and
    - To determine the existing gaps in research which are necessary in order to proceed toward any type of development.

- Development: the translation of research results and concepts into a workable system or component systems which might or might not achieve the desired goal.

- Demonstration: that which demonstrates the effectiveness of a specific methodology or technology and that which demonstrates that proven technology to the greatest amount of potential users. The demonstration "value" is determined by how well the technology increases performance during the process of learning; the demonstration "effect" by how quickly other potential users accept and adopt the validated technology.

Priorities

The U. S. Office of Education will consider funding a CAI proposal if the anticipated results of the project tend to meet the following priorities.

- The technology will increase the quality of programs at existing costs or provide the same quality of performance at reduced costs;

- It will develop criteria for measuring CAI effectiveness in specific subject matter areas;

- It will provide the opportunity to determine the procedures and costs of developing concurrently a flexible management system to realize the cost savings resulting from CAI;

- It will have direct relevance to and relatively quick payoff for on-going or new education programs initially supported by USOE or initiated by local schools;

- It will provide an opportunity for the community to participate in the planning or evaluation of the new project;

- It will utilize private schools, non-profit organizations, and industry which lend themselves to maximum resident involvement, as well as local school and university systems in the project.

In all cases consideration must be given to whether funding might be available from another Federal agency within a reasonable period of time.

What the Office of Education Expects From Individuals or Institutions

- To read these guidelines carefully and thoroughly and then submit a proposal to a Federal agency for funding or have the agency act as a catalyst in seeking funds from other agencies;

- To contact the Office of Education either by personal visits or telephone to ascertain whether or not the proposal would fall into their jurisdiction and meet priority areas; and

- To be very precise and brief in answering all of the questions in the guidelines.

What Individuals and Institutions Can Expect from the Office of Education

- After receipt of a proposal by the relevant division of USOE, upon request, the prospective grantee will be told that the proposal:
    - Is being actively considered;
    - Does not presently fit into priority programs but will be considered at a later date;
    - Fits into a priority area but needs to be refined and perhaps modified;
    - That further questions need to be answered before any decision is made; or
    - That the proposal has been rejected and that application should be made elsewhere.

- If the proposal is being actively considered, a request might be made to make an oral presentation to relevant Office of Education officials and representatives or other interested Federal agencies. The names of the participants and those officials in other Federal agencies whom the grantee wishes to be present should be sent at least a week in advance. Material (e.g., flipcharts) should be requested which might provide assistance in the presentation.

- If the project is funded, a Project Manager will be assigned to the project. His duties will include among others:
    - Providing contact between the Office of Education and the grantee;
    - Assisting in preparation of interim progress reports;
    - Making frequent site visits;
    - Renegotiating and revising facets of the project whenever such cases become necessary; and
    - Coordinating the project with other relevant projects to minimize duplication of effort and maximize the transferability of proven techniques developed in other programs which might increase the performance of this project.

A Word of Caution

These Guidelines indicate that certain areas of conflict might arise. For example:

- Between the autonomy of the researcher and the job that the Office of Education wants him to do;

- Between the development of uniform standards for judging similar proposals by requiring strict adherence to the guidelines and the creation of novel and imaginative solutions to old problems.

Potential conflict in the former necessarily results from the limited funds which have been allocated to support CAI programs. The latter, from the effort of the Office of Education to develop a problem-solving capability to initiate a comprehensive program to determine the relative effectiveness of CAI and diffuse proven programs throughout public education.

Specific Guidelines for Submitting, Soliciting, and Evaluating CAI Projects

Relevance to Office of Education Priorities

The prospective grantee should be very specific in defining the specific research and development or learning problem and sub-problems for which he will be seeking solutions as well as showing the relationship between the sub-problems. Various techniques have been developed to solve similar problems. Certainly, this is encouraged. However, the specific technique, method, or technology should be rigorously spelled out.

Anticipated results under various conditions must be stated. Certain results should have direct relevance to Office of Education programs. These need to be made explicit. On the other hand, some might support functions provided by the Office of Economic Opportunity, Department of Labor, or by other Federal agencies. These benefits should also be noted.

Demonstration: What, To Whom and How?

The demonstration "value" of the CAI project is measured by how well it achieved its anticipated level of performance which in turn should be stated as nearly as possible in objective terms (e.g., to provide the remedial education necessary for a migrant worker to pass the examinations qualifying him for a MDTA training program).

The level of performance which is regarded as validating the technology should be stated, and how the process will be measured should be described.

To demonstrate that a specific CAI mode of presentation (e.g., problem solving, tutorial, etc.) technique is better than others is one thing; to assume that an efficient technique will be accepted and adopted is another. To whom the demonstration is directed should be stated (e.g., parents, school board, local political groups, teacher, et. al.) and why, if the situation is unique. The Office of Education would also be interested in knowing what techniques will be used to expose potential users to the project (e.g., by defraying travel expenses, using television media, newspapers, etc.).

To What Extent Can The Validated CAI System, If Successful, Be Economically Replicated? If Not In Total, What Elements?

The Office of Education would like to view many of the potential CAI projects as investments where the costs of research and development can be amortized if parts of the program can be replicated in general education programs. To what extent can parts of the system, if not wholly, be replicated without the use of highly-skilled personnel? Similarly, an important criterion for selection is how and under what circumstances can the soft material (curricula, tests, programmed content, etc.) be adapted to other educational equipment and situations.

What Are The Relevant Costs?

The relevant costs to society in general would be those resulting from the failure to use new and efficient techniques. Hence, it is necessary to know whether or not there are present alternatives to using the technology or parts of it (e.g., the hardware element). If research and development costs are large, anticipated alternative opportunities of potential application should be indicated. Since many of the potential research and demonstration projects will be viewed as investments from which validated parts (e.g., the "software") can be adapted and used widely at low additional costs, the greater the number of potential applications, the quicker the potential amortization of the research and development costs. It should also be noted that costs involved in a project can be rationally judged only if the benefits to be derived are made explicit.

A correct allocation of costs is critical. CAI research and development projects should follow the general framework presented in the attached Cost Matrix Allocation Illustration (see Figure 22), modified as necessary. Similarly, a second breakdown should indicate the approximate amount of research, demonstration, and evaluation funds allocated to the functional areas of the program (e.g., to train non-professionals to instruct preschool programs; to develop instructional software and curriculum for the program, etc.). Joint costs should be estimated, weighted, and allocated to separate functions at the discretion of the potential contractor and/or grantee.

The section of the proposal explaining the costs of the potential project should also indicate what is conceived as the state of the art and how the project will contribute. Assumptions should be made clear concerning the current availability of equipment and techniques as well as those developments which will have to occur before the project can be carried to completion. The Office of Education would also want an opinion of the promise offered for continued improvement and development of the equipment and program content beyond the limits of the proposed project. Similarly, if the project is radically novel or unique, there should be an explanation of how, why, and to what extent.

If the approximate cost "curve" of expanded use of the validated techniques and methodologies developed in the project is not obvious in the budget, a short paragraph should be devoted to this aspect. At the same time it is very important in explaining the cost "curve" to separate the hardware costs from the soft material or program content costs. A general statement needs to be made about the historic reliability and "ruggedness" of developed equipment which will be used. This statement should also include the general availability of replacement parts and components.

When Can the Office of Education Expect Results?

Stipulation of payoff time is necessary. Most of the research and development projects which will be funded will yield relatively quick returns. To assist in planning, the Office of Education needs to know after what time period developed and tested component systems (e.g., teaching manual, curricula, etc.) which might be adapted to on-going and/or new educational programs can be expected. If the proposal is geared to a major breakthrough with high risks in the development as well as the potential application, an explanation should be made as to why it is advantageous for the Office of Education to fund the project.

	Contr. & Negotiations	Organizational	Managerial	Training	Prod-Prototype	a) Hardware(s)	b) Soft Material	Quality Control	Mfg. First Vol.	a) Hardware(s)	b) Soft Material	Prod. Documen.	Spares-First Vol.	Maintenance Training	Inv. Control-Spares	Expendable Supplies	Replacement	Rework	Mass Production Volume	a) Hardware(s)	b) Soft Material	
A Date To																						
1. Applied Research																						
a. Systems Design																						
b. Production Specs.																						
2. Exploratory Develop.																						
a. System																						
b. Component Systems																						
3. Demonstrations																						
a. Value																						
b. Effect																						
B Date To																						
1. Applied Res. (Eval.)																						
2. Engineering Develop.																						
3. Demonstration																						
4. Operations																						
C Date To																						
1. Applied Research																						
2. Development																						
3. Operations																						
4. Evaluation																						

Figure 22. Cost Matrix Allocation Illustration

How are the Different Phases to be Evaluated?

A necessary condition for any evaluation is a prior precise statement of the problems, the goals desired, the working hypotheses, and the techniques to be utilized to measure success in objective terms. Although the Project Manager of the project and other similar ones will constantly provide the Office of Education with general evaluation procedures, it is important to state at the outset how the project is to be evaluated and at what phases. It is important that specific phases be delineated and a log of the progress of the project be made available in a form which can easily be understood.

What is the Relationship of the Project to Existing Proposals Funded by Other Federal and/or Non-Federal Agencies?

The proposal should indicate how the project is related to similar projects, if any, which are presently being conducted. Parallel research and demonstration efforts seeking solutions to similar problems are often desired. Whether the project complements or supplements other efforts or utilizes techniques differing from existing projects should be explained.

What is the Competence and Commitment of the Potential Grantee?

All relevant disciplines necessary to achieve the stated goals should be considered. Managerial talents as well as specialties required should be explained. Methods (e.g., subcontracts) to obtain these specialties and talents should be explained. Although many consultants and advisors might be required, the major commitments of the principal investigators in terms of the percentage of time to be devoted to the project should be pointed out. A list of each of the other major commitments of the principals as well as his qualifications for providing his specific service should be appended in a personal vita.

PUBLIC POLICY ISSUES

The cost model in Section I indicates the pressing need to introduce better management and decision-making practices into public education. The guidelines in the second section attempt to suggest some feasible alternative procedures for implementing this goal. In this last section the larger public policy issues will be discussed. However, it is not enough to mention the issues; they must be viewed in light of a philosophical change in public policy relating to education and other public service programs as well as to the present posture of a new, potentially cautious industry — the educational technology industry.

Posture of the Industry Involved in CAI

Over the last four years there has been a trend by the Federal government (and to a lesser extent state and local governments) to use industry's problem-solving capabilities in public programs such as transportation, housing, health services, and education. Many of these companies, formerly in the aerospace-defense sector, find the defense support-type market, including education and training, attractive because of their familiarity with it, and welcome the opportunity to use it as an initial market to gain experience which can be applied in the traditional public education market. This is especially true for those firms who want a controlled-type training situation in which to test new, sophisticated technology.

At the same time, those companies with validated hardware and software are "tooling up" to enter the general education and training market through poverty programs, prison system training, and several O. E. funding titles of ESEA. High government officials have become aware of this industrial activity and its potential for applying the new technologies being developed in industrial laboratories. Yet, there exists a degree of uncertainty as to how best to use these resources and to what extent industry will become an ally for change.

Industrial entry into the education market resulted from two causes: (a) the shift in the composition of the DOD-NASA budget beginning in 1962-1963 causing the defense-aerospace industrial sector to look into other existing potential public service markets or those which could be created; and (b) the recognition that education was a growth market, nearly doubling in dollar expenditures over the last decade to more than 50 billion dollars in 1967.

In both cases the nature of the problems involved were slighted. First, there were fewer "conversion" problems in industry than in government. Industries, especially those formerly in the defense sector, sought to sell solutions; yet, governmental procurers did not have the expertise and manpower capabilities to define solutions desired in terms of performance. Rather, they continued seeking traditional input products (textbooks, bricks, asphalt highways, etc.) from industry. Secondly, the dollar size of the education market was misleading because the nondollar and nontechnical barriers to innovation were greater than the technological ones. In both cases, the problem of creating new markets became obvious.

A survey of the teaching machines industry conducted by the Harvard School of Business Administration in 1960 and 1961 found at least 60 companies manufacturing teaching machines for commercial use. A survey conducted by the Office of Education in 1962 found at least 132 firms who had commercial teaching devices and instructional programs available for public consumption (this survey included publishers of programmed learning instructional material). Several surveys conducted in 1966 revealed at least 60 commercial firms who had devices which could utilize largely programmed instructional material for training and education. Although the surveys' common denominators were such that hard conclusions could not be reached, the widely-held contention that the teaching machine industry reached a peak in 1962-1963 appears to be supported by the above. The large majority of these companies were relatively small and usually had weak financial bases; similarly, most were selling "products" rather than integrated solutions to particular education problems.

The recent activity began around 1963, when the large electronics and defense-oriented divisions of large corporations began acquiring smaller educational technology companies and expanding their own capabilities. The major difference between these companies and those involved in the earlier teaching machine movement was their strong financial basis plus the vertically-integrated nature of the capabilities (products) ranging from job analysis through evaluation of a CAI prototype.

Present Posture

At the present time there are at least ten large companies whose commitment to CAI is long run with promise of continued (4-5 years) internal financial support for its development. One of the companies is devoting about 20 percent of sales to internal R & D. In addition, at least 20-25 firms have specialized services (job analysis, curriculum development, systems design, etc.) which can be used on a subcontractual arrangement with other companies that do not presently have integrated CAI capabilities.

The philosophy of many of these companies is generally as follows.

- "Let's use existing hardware, terminal and other, and concentrate our efforts on the development of functional software and curricula;"

- "We must find actual training programs in which we can experiment and at the same time develop software and curricula through action research 'feedback'. Once we have learned enough about the learning process, we can then concentrate on the type of hardware configurations which will be the most compatible and conducive to learning. We cannot expect much hard data from the university R & D centers;"

- "Cautious urgency is the word; yet, we must choose the consumer to whom we sell our almost 'debugged' equipment in order to minimize any marketing blackeyes while the market is being created;"

- "The firms will have to be rather cooperative, at first letting each other develop specific curricula and functional software which is compatible with each others' pieces of hardware; after the market is created then we will be in cut-throat competition;"

- "In order to increase the probability of amortization of costly R & D, the initial market must be a "hedge", yet in itself large enough to show economy of the CAI system. The military training program is a good hedge for curricula development in that there exist several civilian counterparts such as junior colleges, technical schools, and in-house industrial training programs. Also, the unit sizes of the various programs are larger than most others."

It is interesting to compare the comments made in private by some high officials in the industrial sector concerned with CAI to public utterances by other spokesmen. A recent example of the latter occurred at the first annual symposia of Project ARISTOTLE, at which time industry's credo was proclaimed.

- The responsibility for education is a public trust resting primarily in the hands of professional educators.

- Educational objectives, curriculum content, and methods of education must remain largely the province of discipline specialists and educators. Professional scholarship and integrity must be prime goals.

- Educational technologies and curricula are only means. The purpose must be to expand the ability of the educational system to realize its objectives.

- The education industry must share the risks of initiative in developing useful technology. The results of these efforts must be presented promptly and responsibly.

- The establishment of valid industry standards must be a continuing endeavor. These standards must have the fullest possible understanding and support of professional teachers and administrators.

- Advertising of educational technology must be based on validated experience. Competitive practices which constrain education's advancement must be avoided.

The dichotomy of industry's position was recently posed by the president of one of the largest firms developing CAI systems. "Either we develop what the education leaders tell us they need or we attempt to develop quality goods and services hoping that the system will change its practices so that a market will be created. Rather than asking whether or not industry will provide the catalytic role in introducing change, I would like to know how serious the Federal government is in providing us the opportunity to realize this role. Very simply put, it is the responsibility of the Federal government to ensure that dollars flow from Washington in such a way that it is profitable in the long run for industry to move in a direction which serves rather than undermines the public interest in education."

The import of the above statement can only be understood in light of the uniqueness of the industry and the problems which confront it.

Unique Industry Facing Unique Problems

One of the most interesting phenomena resulting from the attempt of the CAI industry to penetrate the education market has been the recognition of some of the fundamental causes rather than symptoms of the failure of our American educational system. An understanding of these problems in light of the unique opportunities offered by this industry is requisite for viewing the action or inactions of the firms developing CAI as well as rationalizing public policy issues.

First, the CAI industry is unique in that there appears to be a tacit agreement originating at the high executive level for inter-company cooperation. This stems from several reasons.

- Development of functional software including curricula is very expensive and the return on particular development is uncertain. The sales through copyright licenses are uncertain because copyrights are difficult to enforce. There would appear to be an incentive for companies to "divide labor" in terms of developing software and curricula which can be used by various manufacturers on various equipment. Whether this incentive is enough to perpetuate compatability of software with a variety of equipment is not clear.

- In terms of promotion and advertising "cooperation", it would appear that the attitude of most of the manufacturers is that as the market grows they will maintain existing shares. It is too costly to compete while the market is being created.

- In many cases the company executives, under whose responsibilities the computer-assisted instruction divisions fall, are recent "graduates" of high level Federal positions, who previously have had important positions in education and/or directly related areas. Their initial impact on education improvement through the use of sophisticated technology will depend on the degree of social responsibility which the particular individuals have, the rapport each has with the other, and their tenure in their present positions in industry. The latter is dependent on their ability to sell their corporate management on the long-run market potential of CAI, which in turn is dependent on public policy which tends to promote management improvement in schools as well as direct support for CAI development.

- At the present time the leaders in the field do not appear to be willing to sell their equipment to users who are not capable of using it effectively. Similarly, there exists extreme pressure by the executive level on the marketing people to sell only "debugged" equipment, especially if such operations are to be exposed to their potential large user market, which is usually composed of ultra-sensitive local groups associated with education.

Second, the educational technology industry, of which CAI is a part, consists of three general types of firms: (1) "solution-oriented" firms, largely from the aerospace-defense sector; (2) large product firms ranging from audiovisual equipment to textbook publication; and (3) large electronic firms who through mergers, joint ventures, or acquisitions have teamed up with textbook publishers. Although many dollars were invested (approximately one billion dollars over the last two years) and corporate vice-presidents have proclaimed publicly the new solutions to educational problems which would flow from their laboratories, there is evidence of increasing conservatism among the management of large corporations involved in CAI. While it is partially a result of initial overoptimism based on a particular marketing report which at least twelve major companies used for analysis, it stems also from the inability of the Federal government to deal effectively with industry. Solution-oriented companies are finding it difficult to get money whether from Federal or local sources, to support R & D, and, most important, to finance procurement of their "systems." Office of Education funds are still allocated largely on existing "inputs" (equipment, facilities, textbooks, etc.) rather than total package "solutions." Or if "performance-based" requests for proposals can be developed, quality evaluation of the proposals is often adequate. Or, if quality evaluation occurs, it is piecemeal creating sub-optimization according to functions under separate titles or funding categories.

Because Federal money is readily available for existing products, ironically much innovation that has occurred in industry is concerned with reducing production costs (e. g., computer-based instrumentation control of printing textbooks)... A case of the "tail wagging the dog" regarding the use of computers in education. As a result, textbook divisions of corporation mergers or acquisitions show the greatest return on investment and are having a larger "say so" in the long run planning decisions regarding the corporations' allocations of R & D dollars for new "solutions." Failure to show short-run feasibility might preclude the ultimate application of radical solution-oriented computer-based educational technology.

Third, the management problems of public school education have been forced to the surface as the CAI industry has attempted to penetrate an autonomous, monopolistic institution. Rather than discuss in detail the problems, it will suffice only to mention them and their relevance to the eventual use of CAI in public education.

- Due to the lack of criteria for measuring learning effectiveness, decision making is based largely on cost reduction without regard to learning achieved. Teachers and administrators usually decide on the approach which minimizes maximum inconvenience. If decisions were based on learning "produced" and teachers and administrators were rewarded on merit according to learning, teacher resistance would become minimal and the learning potential offered by CAI might be realized.

- Because of the traditional autonomy of schools and their monopolistic position (in terms of student's time and the lack of competitive educational opportunities), public schools have no need to develop quality control over their "products" — the students who graduate, dropouts, or failures. Until public education is made accountable for its products, little planned change will occur.

- School budgeting practices almost preclude the opportunity for introducing technology that requires large capital investment. Not only are most budgets based on year-to-year periods, but often they do not coincide with Federal budgetary cycles thus leaving seldom more than two or three months for school planning. The net result has been depicted in the increased sales volume (since ESEA was passed) of audiovisual equipment which is seldom used even though it may be of high quality. The inability of the schools to do much more than suboptimize in program categories which are outmoded is largely due to the accounting and programming structures forced on them by state and other authorities.

- Procurement policies inhibit CAI development and application. On the Federal level, there exists separation between R & D and user pruchases since O. E. has little control over operations of the 20,000 school districts across the country. With this lack of vertical integration, it is even more incumbent on the R & D sponsors to either direct efforts to user-conceived problems or assist the user in reformulating the problem in light of new solutions which will be available. At the same time, a concerted effort is required to develop a capability among the purchasers to procure effectively from the industrialists who would sell sophisticated educational technology.

- In order to realize the projected time savings through individualized self-paced CAI methods of instruction, management systems which provide flexibility in terms of scheduling, etc., will have to be introduced into public schools. To do so will require a seriousness about education on the part of parents, school administrators, and teachers. This recognition has caused several firms who initially gave highest priority to CAI to turn to computer-managed instruction, not only because it provided them the opportunity to develop their learning curve on the pedogogy of learning but also as the best approach (largely through osmosis) to change the atmosphere of decision making, a prerequisite to the effective introduction of CAI.

In summary, systems procedures have not been developed in public education. The individual school manager has not been forced to define the problem (or opportunity) precisely, to note the alternatives available and their total costs, and choose the most efficient alternative according to performance criteria. Until this problem has been analyzed, solutions sought, and attempts made to implement and test them, the opportunity to experiment and utilize CAI effectively will be small. It is encouraging and significant that the Committee on Economic Development made up largely of leading industrialists, most of whom have little direct interest in the education market, is the first large and responsible body to recognize the relationship between efficiency and the opportunity for capital-intensive innovations in the last of the manual trades — American education.

Philosophical Change In Public Policy

With the exception of the defense and aerospace business during the fifties and early sixties, the Federal government is only now attempting to utilize industry in a perscriptive manner — namely, a return to the initial use of corporations which were chartered by the state to conduct work for the state and in public service programs. In the mid-sixties, opportunities were provided for industry to enter new markets by either creating market opportunities through subsidization (e.g., housing) or through R & D expenditures (e.g., education and poverty programs) or combinations (e.g., atomic energy for peaceful uses). Rather than follow the letter and intent of traditional government regulation of business through proscriptive policies based on the Sherman Antitrust Act (e.g., "to maintain existing competition"), the Federal government began to use its market creating power to promote competition by enticing innovation or providing the opportunities for companies who would not or could not provide internally-financed R & D the necessary support to enter markets which they would normally not be able to enter. This philosophical change has negated the usefulness and effectiveness of certain regulatory agencies and created confusion and problems, but at the same time it has provided opportunities which have not been recognized generally by industry nor by public policy makers. When this philosophical change occurred in the defense R & D area, a special procurement act was passed; no such act has been passed regarding the prescriptive use of industry in non-defense public source programs. These problems and opportunities have created educational policy issues which affect the potential use of sophisticated technology including CAI.

Public Policy Issues Regarding CAI

Cost-Sharing Rationale

In this area the principal questions center around to what extent Federal agencies are willing to support R & D in computer-assisted instruction in (a) hardware development, (b) software development, and (c) curricula development.

If (a), then in what component elements of CAI (e. g., light pointers, CRT, plasma discharge, etc.)? If not (a), but (b), then in what courses? If not (a) or (b), how can sophisticated hardware and software presently being developed by the government under contract or in laboratories (e. g., ARPA/DOD, Regional Educational Laboratories, etc.) be made available to industrialists in an equitable and disinterested manner to conduct pilot programs? If only (c), how much of the development cost should the initial user have to bear if there are other potential users (e. g., DOD vs. 20,000 school districts)?

What other factors affect the nature of the cost-sharing rationale? If hardware development is to be supported, should the government have exclusive or non-exclusive royalty-free rights? If copyrights on software are difficult if not impossible to enforce, is not the copyright problem a moot question? If so, what other arrangement can be developed to ensure that industry has an incentive to do quality research and development on software and curricula? But, to the extent that industry finances its own R & D and pilot programs, will not their proprietary rights impede the diffusion of results non-supportive of their equipment into operational use in schools and other educational settings? Perhaps this is a justification for federally-financed R & D.

Public Domain Policy

The Office of Education "public domain" policy was made explicit in an article in Higher Education, in July 1966. The rationale behind this policy is traditional, and thereby overlooks the unique problems and potential of the CAI industry. A less traditional approach might in the long run increase the diffusion of educational innovation greater than any other policy, given the present structure of the U. S. educational system. Public domain policy can be best viewed in terms of incentives.

First, the question of incentives to develop quality CAI hardware and software. In most cases, existing hardware has been the basis of CAI systems, with minor modifications in auxiliary and terminal equipment. Recently developed machine languages (e. g., APL) can be used for education and other purposes. Hence, the software area is the element of CAI which is affected most by public domain policy. It must be recognized that Federal support of educational software development can evolve in two ways — direct R & D financial support and providing the opportunity for demonstration and evaluation in a Federally-supported and in many cases Federally-operated training and/or educational program. This latter support has two dimensions — if there exist potential markets outside the test-bed areas (e. g., the testing of electronics training via the CAI mode in the Army has potential in both trade and vocation training schools as well as industry in-house training); and if the CAI technique being tested is in a stage of development which requires a laboratory type situation where experimentation can occur in actual training and/or educational programs (e. g., prison systems, certain military programs, isolated Indian education programs, etc.). An inflexible public domain policy at this stage of development of CAI which does not take into account the differences in industrial motives is both damaging and stultifying.

Second, the problem of diffusion of innovation in education is directly related to public domain policy. The basis of the problem is that while the Office of Education can support the development of sophisticated CAI systems, there is no assurance that the 20,000 autonomous school districts in the United States will accept those systems justified on cost effectiveness or other bases. As mentioned earlier, the DOD has control over both R & D procurement and use of those techniques proven effective; yet, even here it has been shown that the gap between R & D personnel and users is great. Clearly, unless bureaucracies, either R & D or training/education institutions have the necessary incentives to reduce the time from research to adoption, the process will be slow, and assuming altruism on the part of the organization, only builds optimistic expectations. It is noteworthy that industry involvement has been an extremely critical factor in the diffusion of innovations in military education and training.

Standards of Measuring Effectiveness

At the present time, few performance-based criteria or standards exist for comparing the effectiveness of one CAI system against another or CAI against traditional techniques. Sponsoring agencies have failed to direct R & D projects with an emphasis on gathering hard data relating to the effectiveness of new technology in education and training. To a lesser extent, industries have been negligent in their own training programs. The net result has been that CAI is usually compated to that which a tutor does without attempting to find out what a tutor does in fact do.

It is probably true to say that because of our limited knowledge about the process of learning, a common denominator for measuring effectiveness of various techniques between various subject matter areas will not be developed in the near future. The relevant comparisons will have to be among various techniques in a particular subject matter area. To accomplish this task, pilot programs which are recognized as being experimental, will have to be undertaken with close project management control in the design, implementation, and evaluation of the project to develop these standards. At the same time, we must provide measures to guard against the development of standards which force an unjustified movement to standardization which may become an obstacle to further innovations.

Once the question of "what" and "where" regarding the developing of standards is determined, "by whom" deserves priority concern. Technical and managerial competence is an important criterion for selection. Another is the ability to determine users' problems. Undergirding these criteria lies the criterion of "disinterest" and the respect of the university, the school, and industry. The form of the mechanism is important — (a) Should it be a university-based operation?; (b) Will "not-for-profit" organizations acting as buffers between industry and governments provide the best solution?; (c) What are the advantages of using a consortium of hardware manufacturers hired for curricula development by users and managed in a COMSAT manner?; and (d) Can groups such as the American Education Industries Association and NSIA effectively assist in the development of standards?

Time Lag Between Invention and Diffusion

Federal officials from the President down are concerned that "many technologies now exist but are awaiting demonstration of their practical value and the creation of a market." The question is where are the opportunities which offer both the "natural laboratory" situation and the atmosphere conducive to experimentation to evaluate and demonstrate the effectiveness of CAI? The atmosphere of local schools is not conducive to Federally-initiated experimental projects nor do they have the optimal size and manpower capability to use CAI effectively for demonstration purposes. Job Corps and Community Action programs (CAP) have not supported any development of CAI. Although the Office of Education has supported software and curricula development, it has been tested largely in the laboratory rather than in a classroom, with a few exceptions.

Industry has used CAI for problem solving and simulation for several years. The prime example is IBM's use of CAI in its maintenance services training program. But this opportunity is usually available only to the large vertically-integrated companies. Certain universities are using CAI to assist in problem-solving functions; for the most part, however, the objective is research on instruction with little emphasis on costs or effectiveness.

In terms of a "proving ground," DOD education and training programs offer a generally favorable climate because of large scale unit size markets; an atmosphere which is relatively conducive to experimentation; skilled manpower capabilities; and the size to afford risks and uncertainties of cost effective use. The Office of Education-DOD support to the Naval Academy to design a multi-media instructional system, including CAI is exemplary. Similarly, the Assistant Secretary of Defense for Manpower recently stated at the annual ARISTOTLE meeting that the military dependents overseas schools offer a tremendous test-bed for new ideas and techniques which might have general application in public education.

In summary, the philosophical change in public policy inherent in concepts like "creative federalism" has created problems and has forced the issue to the forefront. To approach these problems with the attitude of forcing them through pre-World War II "solution molds" will neither generate rational thinking nor unleash the potential opportunities offered by the new educational technology.

Feasible Public Policy Alternatives

There exist at least two general but not mutually exclusive areas in which novel public policies and instruments could contribute not only to the timely development but also to the expanded use of efficient CAI systems over time. One is concerned with direct R & D Federal support for CAI development and testing; the other is concerned with creating the necessary environment which is conducive to innovation generally and specifically to the demonstration and realization of performance increases from the operational use of CAI. The latter case calls for better management procedures on all levels of government concerned with education.

Use of Federal Procurement Policy to Encourage Innovation

This particular policy instrument is implicit in the prescriptive policy of government-business relations. While Federal agencies will defend the rationale, few have adhered to it in practice. There are three basic aspects of this policy instrument — the use of procurement policy to force industry and other suppliers to innovate to meet certain specifications; the conversion of archaic procurement specifications and regulations to performance-based specifications and regulations in order to free industry to use novel approaches in solving problems; and the use of marginal R & D funding to determine feasibility of new techniques hoping to provide "go-no-go" decisions for public policy decision makers.

The rationale for this instrument is based on several arguments. First, the Federal government is the largest single purchaser of training and educational goods and services, with the DOD as the largest single Federal agent (about $3 billion annually). Because of sheer volume of the market, industry often finds it advantageous, especially outside the defense area, to conduct internally-financed R & D to meet Federal specifications.

Second, in certain areas (e. g., housing and health services) Federally-operated facilities are not subject to local building codes, unionization, and other restrictions on innovation. Hence, the opportunity for the use of performance-based specifications is great (e. g., teacher resistance to teaching machines in military training is relatively small). Three parallel contracts were let in December 1967 by the DOD to industry to allow them to innovate in the housing area. Industry accepted largely because of this freedom and the opportunity to get a foothold in the civilian market.

Third, in areas where the impact, both positive and negative, of the new technology is uncertain, the Federal government has accepted the burden of determining both technological feasibility and the social impact, partially because it can not only provide the initial encouragement for certain companies, if proven feasible, but also discouragement if the total impact is shown to be disadvantageous to society. (For example, the large Federal support for the development of the SST based on the uncertainty of the sonic boom effect; the analogy here might be that while CAI is effective, it might teach the wrong things more effectively.)

The possible impact on the timely development of CAI lies in several areas. First, such action by the Federal government could be the initial step in the creation of the market for CAI. Through the use of performance specifications in terms of learning not in terms of procedures, the potential of CAI can be best determined, or at least the criteria for measuring its success can be determined.

There exists a tremendous opportunity to create a structurally-competitive industry which in the long run will provide quality goods and services at lowest costs through long run competitive efforts by other firms. A precedent exists for such action by the Federal government. In the early fifties, the Department of the Army saw that the semiconductor developed under contract by Bell Labs had other than purely a military application. Thinking of the future, it let nine parallel R & D efforts to provide an industrial base which spawned at least 50 firms by 1958 who were producing semiconductors at a cost factor of ten times less than the initial volumes. The same opportunity exists in the field of CAI if a rational plan is devised. In the absence of a rational policy for supporting CAI development directly or indirectly (e. g., such as the Naval Academy multi-media project), it is conceivable that such support could create a structurally noncompetitive CAI industry possibly requiring remedial antitrust action five years from now to break up companies whose "thrust on" monopolist position was created in the first place by another branch of the Federal government. The Antitrust Division of the Department of Justice is aware of this problem (suits were recently brought against 18 book publishers in New York City).

The use of performance specifications and the potential market-creating power of Federally-operated programs using CAI will separate those companies which are sincerely interested in developing quality goods from those with lesser intentions. The mere knowledge that a firm is willing to make minor internal R & D efforts to meet certain specifications and that they are willing to have their approach tested and demonstrated to their potential market warrants serious consideration as indicative of their true intentions and commitment.

A plan of action based on the above might be an Executive Order similar to the one dated November 17, 1965, (11258) in which the President asked Federal agencies to use their procurement policies to abate pollutions in their own operations. At the same time, a Presidential memorandum dated June 28, 1966, requested that each agency make every attempt to find new and novel ways of using computers to reduce costs or increase performance in their existing operations. Based on the Government Employees Training Act of 1958, incorporating the substance of the Brook's Bill (on computer procurement), and building on the importance of the Henderson Subcommittee Report on Government Employees Training, such an Executive Order could provide the necessary incentive and limited market for CAI to be tested and demonstrated in Federally-operated education and training programs. Certainly this approach would be in line with the concept of creative federalism in which the Federal government plays the following role in the words of the President who stated in May, 1966:

> "There are numerous cases where the technology is already at hand but is awaiting a demonstration of its practicality and the creation of a market. One contribution the Federal government can make is in helping to overcome reluctance to accept promising innovations by making possible their demonstration and evaluation."

National Foundation for Curricula Development for CAI

One purpose of the Foundation would be to legitimatize R & D, evaluation, and operational use of CAI in a tutorial-socratic mode. Its objectives would be limited to create a large limited market with the critical mass required for quality "action research", development, and evaluation; to develop hard data on pedagogical instructional strategies; to ensure compatibility of programs among various hardware systems which would be available for use to develop, validate, and provide user-oriented material; to develop criteria for measuring effectiveness of CAI; and to provide the opportunity for the development of a learning curve by the Federal government, industrial, and user participants. The existence of the Foundation would be limited to a certain period of time, possibly four years.

Membership would include at least ten of the largest hardware manufacturers of CAI equipment, who would donate their equipment for a limited period of time. Indications lead one to believe that such cooperation of industry is possible at the present time. Software teams from industry, government, and other organizations could be on site on temporary duty. User representatives would also be on site in the early design stages.

Management organization would be similar to COMSAT with "public" board members chosen by the Executive Branch and the remainder by other Foundation members. Financing would include payment in kind from manufacturers and user fees for curricula development. It is conceivable that generally applicable curricula would encourage user consortia with degrees of cost-sharing.

The possible impact of such a Foundation would include among others — necessary critical mass will have been achieved through publicity and achievement for quality development; the copyright issue will not have been a hinderance to curricula development; a large enough competitive industrial base in CAI will have been created; "empire building" in government and non-government laboratories in the R & D stages will have been minimized; the release of proprietary R & D results by industry, presently a problem of unknown proportions, will be minimal; the degree of the language compatibility problem will have been determined, indicating the need or lack thereof for quality standards without unjustified standardization; and the "NIH" factor will have been minimized in the initial phase of CAI usage.

Use of Industry as a Major Diffuser of Efficient CAI Systems

Education is notorious for the long time lag between the availability of new techniques and their widespread use throughout the system. As one solution, the Commissioner of Education has suggested that industry reallocate its advertising funds to quality development of hardware and software leaving the diffusion process to Federal mechanisms like EPIE and ERIC. While this idea is theoretically sound, in education where one page of history is worth a hundred pages of logic, experience leads one to believe otherwise. In fact, in at least one area — military training — it has been shown that industry plays a critical role as a diffuser of innovation. These reasons stem from the fact that it has an incentive, the profit motive. The specific functions provided by industry in the military experience have been (a) a greater incentive to promote the adoption of a new technology than do laboratory personnel; and (b) a focus of continuity because the rate of turnover of military and civilian personnel in training research laboratories is often high, resulting in incomplete projects or the failure to initiate long-run studies.

The major problem with this approach is the development and adherence to high quality standards on the part of industry. It is imperative that attempts like EPIE should be more realistic — in terms of conception of the problems facing users, funding levels of support necessary to do an adequate job, and approach taken to achieve desired objectives.

Improved Management: A Prerequisite for Widespread Use of CAI

The implicit conclusions resulting from viewing the costing model described in the first section and others appearing in subsequent sections of the report points to one glaring defect in the existing policy towards CAI development: the failure to support the development of flexible management at all governmental levels associated with education. Below are listed specific feasible alternatives which would in varying degrees of impact seek to improve the management of United States education, opening the opportunities for CAI and other sophisticated technologies to demonstrate and realize their potential rather than foreclosing it as is the case at present.

Total Package Contracting. At present, among the 56 bureaus involved in supporting education, there exists no one who can evaluate and fund a proposal which purports to build an innovative learning institution from "ground up" to be operational over a period of five years. Rather, components are submitted in piecemeal to evaluators who, because of existing title categorization, are forced to suboptimize. If a lump sum (e.g., $75 million) were to be allocated for innovation; if guidelines rationalizing and aggregating existing Titles were announced and sent to interested local school districts; if a model for determining trade-offs within the proposal were used in evaluation by a respected and capable group of individuals — it might be extremely surprising how innovative and imaginative local districts, with the assistance of responsible industrialists and other interested groups, could be. As the costing model indicates, the full potential of CAI-CMI could then be analyzed. The general model presented above and refined to the degree desirable could provide the basis of evaluation of each "total package" proposal.

Bottom-up Management Approach for Education Innovation. Most attempts to promote innovation have been based on a "top down" approach, i. e., the Federal and/or the state government attempting to force innovation or new ideas down through the bureaucracy. The "bottom-up" approach would direct its attention at the most decentralized "manager" — the teacher — and would develop incentives which would tend to make it profitable for him or her to increase learning rather than improve teaching per se. Contingency management has been applied to student learning and teacher training. What is proposed here is basically its application to administration and "teaching-managing". Pilot programs incorporating the following could be initiated at relatively little additional costs: instructional management systems (similar to and building upon that developed by SDC, NYIT, and through Project Plan); teacher training in instructional management decision making; the necessary automated data management systems; procedures for rewarding "teachers" for students' learning based on objective criteria; and a state incentive grants system for schools in the pilot programs.

The selected grants from the state agency would be based on the background of the target student populations, the time periods required for amortizing costs of capital intensive education technology, and the learning achievement level desired for particular students (e. g., culturally deprived). At the same time the state grants could be matched on a below par level with local district projected salary increases over the next few years; hence, rather than increased costs for the schools, only a reallocation would be required.

Through osmosis two basic phenomena would occur: the teacher will realize the new role he or she has to play if she is to maximize her rewards; and if the data management system to be used by the new "manager-teacher" is computer based, then mere exposure to the equipment and how it can assist the teacher will create a psychological atmosphere conducive to CAI modes of instruction. At the same time the "teacher-manager" will have been involved in the development of instructional strategies thereby developing a CAI "author" capability within the school if CAI use eventually evolves into the particular school.

While the Office of Education has supported several elements of CMI, few if any projects have incorporated all the elements of a comprehensive project as listed above. The stockpile of knowledge gained through on-going CMI projects is large enough to merit the testing of an instructional management system incorporating the necessary incentives for decentralized management improvement.

Data Base Performer's Capabilities. Although certain university-appended centers and laboratories have been using computers in education, their use has been for research on instruction rather than for instructional purposes per se. On the other hand, the serious efforts to use computers for piecemeal instructional purposes on an economical basis have been done in industry. However, because of proprietary reasons and privately — as opposed to publicly — financed R & D, O. E. knowledge of industrial priority efforts and R & D capabilities (hardware and software) are inadequate to either send RFP's or "request" unsolicited proposals. The data on which O. E. can evaluate proposals are inadequate because it is not aware of the actual quantity and quality of skilled manpower which exists in industry. Moreover, with the number of acquisitions, joint ventures, and mergers between electronics firms and book publishers over the last few years, it becomes apparent that an informal "data base" within O. E. needs updating and regrouping. Hence, it would appear that before any serious effort to get industry involved in O. E. - supported CAI, a rational approach on the part of the O. E. would be to require a data base on company interests and software, hardware, and production capabilities in CAI.

In many cases the information needed for the data base exists but is not available for internal management on an "as needed basis." With marginal costs, a reporting format could be developed; data could be gathered from the following sources: the Entelek card index; the Defense Documentation Center, 1498 M research and technology resume series; Task Group #9 Project ARISTOTLE questionnaire sent to over 600 industrialists whose interests lie in educational technology; and the Morgan State data base on CAI. This data base would not only assist in developing and sending RFP's but would also appear to be an essential ingredient in determining priority areas of developmental support for CAI.

Summary

The educational technology industry (including the firms developing CAI systems) is unique and confronted with unique problems. Morever, it is evolving in a period when public policy towards industry is changing in a fundamental sense — the return to the prescriptive use of the corporation in public service areas. Quite naturally, the instruments of public policy are having growth pangs as new mechanisms are being tested and explored. It is essential that this exploration be continued. The use of Federal procurement to encourage the timely development of CAI; the use of industry as a diffuser of CAI systems; and new approaches to improve the management of CAI-related activities and public education programs warrant serious consideration as feasible alternatives which need further scruitiny and study.